JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. LXVIII. AUGUST, 1874. No. 2.

EDITORIAL.

ITEMS AND NOVELTIES.

The Franklin Institute Exhibition for 1874.—In the June number of this Journal, we gave in full, the Rules and Regulations governing the deposit of articles at the Exhibition, and the competition for premiums. In this number will be found the rules for the competitive trials of Steam Engines and Boilers.

The general rules in relation to the awarding of Premiums, differ essentially from those of similar Exhibitions elsewhere. As already stated in the address of the Board of Managers, "in the earlier Exhibitions of the Franklin Institute, a list of Premiums was published beforehand, but experience proved that many of the medals were neither earned nor awarded, while the acknowledged excellence or novelty of other articles exhibited, compelled the award of medals which had not been proposed." This plan was abandoned in 1838, and the following adopted in its place, as given in Rule 11, viz:—"All articles entered for competition will be carefully examined by the Judges, and Premiums will be awarded on such articles as they shall declare worthy—their decisions being based on intrinsic merit, and not because the article happens to be the best exhibited in any particular class."

The adoption of this plan has had the effect of raising the standard

of excellence of the exhibits, and also of greatly enhancing the value of the Premiums awarded by the Institute.

The rules for testing Steam Engines and Boilers are the result of careful consideration by a committee, each member of which has given the subject much study; and it is believed that they embrace all that is necessary to secure accurate results. Every facility will be given for comparing the efficiency of the various Boilers exhibited, by weighing the water and fuel, and also by working the steam through an Engine when practicable, and measuring the power developed both by indicator and dynamometer. Builders should not fail to embrace this opportunity of having their Boilers and Engines carefully and thoroughly tested. The preparation for a supply of water to all classes of Pumps is most ample, and of simple character, and cannot but be satisfactory to exhibitors, saving them much labor and greatly reducing the cost of putting Pumps in operation.

Applications for space are coming in freely, especially for machinery in motion, which will occupy fully one-third of the building. Persons proposing to exhibit, should therefore send in their applications soon, to secure eligible locations.

The Committee has been put in possession of the building two weeks earlier than was promised by the Railroad Company, and the work of preparation is being pushed forward rapidly, so that exhibitors need have no fear about its being ready by the 14th of September, the time announced for receiving goods.

Persons desiring further information will receive prompt attention either by addressing the Committee on Exhibitions, Franklin Institute, or by calling in person on the General Superintendent at his office, south west corner of Thirteenth and Market Streets. K.

A Typical Sun-Spot.—We take great pleasure in calling the attention of our readers to the exquisite steel-plate which illustrates Professor Langley's interesting paper on the Solar surface, printed in the present number of this Journal. We do this for two reasons: In the first place because of the skill and fidelity with which Professor Langley has drawn the spot, as observed in his 13 inch refractor. It is well known that the minute details of the photosphere and of the spots cannot be secured by photography owing to their rapid changes and the tremor of the atmosphere under the high power necessary for their observation. Professor Langley tells us that he has taken the general contour and many of the details from the great spot of

December 23 and 24, 1873; but that he has added to the picture the results of numerous studies of detail in other spots, made during the past two years. While, therefore, this is a typical-spot in the sense of being completed from several observations, it has nothing theoretical about it; everything, even the minutest details, having been actually observed. In the second place, we ask attention to this plate because of the marvellous quality of its execution as an engraving. This we owe to a new process devised by Mr. Samuel Sartain of this city, so well known throughout the country for the high character of his steel-engravings. By this improvement the enormous labor of transferring the minute details of such a picture as this to the steel plate has been obviated and the cost of engraving drawings of this character upon steel, proportionately reduced. We believe we hazard nothing in saying that this plate is by far the finest yet produced of the solar surface. The double-spot drawing, which was reproduced as an Albertype for the *American Journal of Science* for February, has excited the liveliest interest in Europe and has been the occasion of repeated discussions in the French Academy; but the present drawing, executed thus exquisitely upon steel by Mr. Sartain, cannot fail to awaken still greater interest and to be treasured as the latest and best work of the kind done in solar physics.

The Chilian International Exposition of 1875.—By a decree of the Government of the Republic of Chili, an international Exposition will be opened at Santiago on the 10th of September, 1875. This Exposition has for its object not only to make known the progress which the Republic has made since the last exhibition in 1869, but also to stimulate the development of new industries and improved processes, and thus to increase the national production. Chili fully recognizes the great value of her natural productions, especially her mineral salts; and therefore seeks, in this way, to introduce into the country the knowledge necessary to develop these possessions and the inventions by which they may be most economically utilized. The articles designed for the Exposition are classified in four sections, each containing several groups. These are: I, Natural products in the crude state; II, Machinery; III, Manufactured articles; IV, Fine arts. Beside these, there is a special section devoted to public instruction. Applications for space should be addressed to the President of the International Exposition of Chili of

1875, at Santiago, in season to reach that city before the first of January, 1875. Articles included in sections I, II, and III, will be received only between the 1st of March and the 15th of August. Articles belonging in section IV, and in the special section of public instruction, will be received up to the 25th of August. All objects forwarded for exhibition should have a card attached, upon which is indicated: (1) The name of the exhibitor; (2) His residence and address, the price of the article, whether it is to be sold, and any other necessary explanations. Exhibitors having machinery in motion, should indicate in their application the character and object of their machines, and the motive power required. All exhibitors to this Exposition will be entitled: (1) To a reduction of fifty per cent. of the cost of railway transportation between Valparaiso and Santiago, and over all other State railways; (2) To free entry of all articles included in sections I, II, and IV, and the special section of public instruction; articles coming under section III, will pay the respective duties when withdrawn from the Exposition for sale; (3) The commission agree to contribute the sum of 200 francs toward defraying the traveling expenses of any special workman charged with the care of any of the machines or industries sent to the exhibition; these workmen having a *visé* upon their passports by the Chilian consul at the port of embarkation, stating that they visit Chili for the above purpose. Concessions from the steamship lines running to Valparaiso, on freight and passage, are expected.

Non-Combustible Wood.—The English Admiralty have recently made some quite satisfactory experiments at Plymouth, upon a wood rendered uninflammable by treatment, which it is proposed to use in the construction of naval vessels. These experiments were superintended by Vice Admiral Sir William Hall, the wood being rendered non-combustible by treatment with a solution of sodium tungstate. The results prove that wood thus prepared is very much less inflammable than ordinary wood; chips and shavings made of it, though of course capable of being destroyed by fire, cannot be themselves inflamed, and cannot of course communicate fire to masses of wood thus prepared; so that frame work made of this wood resists flame perfectly, at least when not exposed for a long time to a fierce fire. These advantages, however, are diminished by the considerable first cost of preparation, as well as by the increased weight of the wood after treatment. Before giving to the inventor of the process,

Dr. Jones, the sum asked by him for the use of his process in the British navy, the Admiralty have ordered new experiments. Two small vessels are to be immediately constructed, of exactly the same size and character, the one of the prepared wood, the other of ordinary wood. They are then to be similarly prepared and fired. In this way, it is believed that the real value of this method, if not in preventing, at least in retarding, fire on shipboard, may be satisfactorily tested.

The Gramme Machine as a Source of Power.—The new thermo-electric battery of Clamond seems fully to answer the expectations at first formed. For galvanoplastic work it has already been adopted in many of the large establishments of Paris. It is now proposed to combine it with the Gramme machine to form a motor for light work. Recent experiments have shown that the ordinary small Gramme machine, used for illustrating the principle only, can furnish when driven by three Bunsen cells, a force of two kilogram-meters. Now since two Clamond elements yield the same amount of electricity as three Bunsen elements, and consume 300 liters of gas per hour, it follows that the above amount of power, abundantly sufficient to run a sewing machine for example, can be furnished at an expense of 1500 liters of gas for five hours' work, at a cost here in Philadelphia—assuming gas to cost $2.25 a thousand feet—of nearly twelve cents.

On the High Temperatures Actually Possible.—Several memoirs upon the highest temperatures actually and theoretically attainable have lately been presented to the French Academy. M. Cailletet has been studying the influence of pressure on combustion. He finds, by means of an ingenious apparatus in which he has been able to burn not only a candle, but also a wick fed with alcohol, in highly condensed air, that the light gradually increases with the compression, finally becoming dazzling and so brilliant as to rival that of phosphorus in oxygen. But then, however, if the pressure be increased, the brilliance of the light diminishes, the flame becomes smoky and flakes of lamp-black are deposited. From this it is clear that the temperature of the combustion increases with the pressure up to the point of dissociation of the hydrocarbon gases of the candle. The same fact was shown by the spectrum; the spectrum increased with the temperature up to a certain limit, which could not readily be passed. From these facts Deville draws the conclusion that it is very decidedly an error to estimate the sun's temperature at several millions

of degrees. These experiments, as well as those of Berthelot and his own, go to show that there is a limit to possible temperatures and that a burning body cannot produce heat of an indefinite intensity. "Perhaps" he says "the temperature of 2000°C. is the highest temperature which can exist in the universe." M. Violle concludes from some experiments which he has made, that there cannot be a temperature higher than 1400°C, anywhere.

The Suez Canal.—The last Bulletin of the Suez Canal Company contradicts the rumors which have been circulated, particularly in England, concerning the filling up of the canal with sand. It asserts that the experience of the past five years has shown that it may be kept open without special difficulty. With reference to the Austrian Corvette Friedrich, which, it had been asserted, was grounded two days and two nights in the canal, and was three days in getting through, the Bulletin gives the following facts: The corvette left Port Said, on the 31st of May, at 4.50 P. M., and arrived at the gates of kilometer 24 at 7.45; at 8.44, one hour after, she was through and the next morning, June the 1st, she left for Suez, where she arrived without difficulty. Moreover, this corvette drew only 5·9 meters of water; while vessels have passed through both before and since, drawing much more. Thus for example, on the 31st of May, the English steamer Ajax passed through, drawing 7·16 meters; June 26th the English steamer Eldorado, drawing 6·81 meters; June 13, the English steamer Coromandel, drawing 6·86 meters; and on June 28th, the English steamer Qwang Se, drawing 7·01 meters. The company is in possession of no facts which gives it any apprehension that the canal will not readily be kept navigable for vessels of the largest class.

Krupp's Heavy Guns.—We find in the *Revue Industrielle* the following particulars concerning the heavy guns already made and to be made at Krupp's mammoth establishment at Essen. The guns are all made of a special quality of crucible steel. They are all rifled and all have the cylindro-prismatic breech-plug characteristic of Krupp's system. The carriages for naval and coast-service are generally of iron, with axles, rollers, bolts and brakes of cast steel. The guns intended for ship's or for shore use are as follows:

1. A cannon of ·305 meter (twelve inches) diameter, mounted on a shore-carriage weighing 36600 kilograms (36 tons). The steel shell

when charged weighs 296 kilograms (650 pounds,) and the firing charge of prismatic powder is 60 kilograms (132 pounds). The weight of the carriage and chassis is 21 tons.

2. A howitzer of ·28 meter (11 inches) diameter, mounted on a shore-carriage, and weighing 10 tons. The weight of the carriage is 9220 kilograms (9 tons). The cast-iron shell weighs 199 kilograms, (440 pounds,) and the firing charge of powder is 20 kilograms (44 pounds).

3. A short navy gun ·26 meter (10·2 inches) diameter, mounted on battery-carriage, weighing 11800 kilograms (11·6 tons). The weight of the cast steel shell charged is 184 kilograms (405 pounds,) and the charge of prismatic powder for the gun is 37·5 kilograms (8·25 pounds). The carriage and the chassis weigh 8·5 tons.

4. A long cannon ·24 meter (9.4 inches) diameter on a battery-carriage, weighing 15500 kilograms (15·25 tons). The weight of the cast-steel shell charged is 135 kilograms (300 pounds,) the charge of prismatic powder is 24 kilograms (60 pounds) and the carriage and chassis weigh 7·5 tons.

5. A long gun of ·21 meter (8·2 inches) on a shore-carriage, weighing 10 tons. The cast-steel shell charged, weighs 95 kilograms (210 pounds) and the firing charge is 17 kilograms (37·5 pounds) of prismatic powder. The carriage and chassis weigh 7 tons.

6. A long cannon of ·17 meter (6·6 inches) diameter, weighing 5·5 tons. The weight of the cast-steel shell charged, is 55 kilograms (121 pounds,) and the firing-charge is 12 kilograms (26·4 pounds). The carriage and chassis weigh 3·4 tons.

7. A long gun ·15 meter (6 inches) diameter, on a navy carriage. Its caliber is ·1491 meter (5·8 inches,) its length, 3·850 meters (12·7 feet,) length of bore, 3·43 meters (11·3 feet,) weight of cannon 4 tons, preponderance at the beginning of curve of breech 75 kilograms (165 pounds). This gun has 48 riflings, all parallel; the width of the grooves being 3 millimeters (·118 inch,) and the pitch of the twist 9·7 meters (32 feet), weight of the cast-steel shell charged, 35 kilograms (77 pounds); charge of prismatic powder 8 kilograms (17·6 pounds); initial velocity, 460 meters (1518 feet). Weight of elongated cast iron shell charged, 28 kilograms (61·6 pounds); firing charge 6·5 kilograms (14·3 pounds); initial velocity 465 meters (1533·5 feet). The carriage of this gun is designed for corvettes, or for vessels of war of the same class. It is a chassis-carriage, furnished with a friction brake to check the recoil in addition to the ordinary

pulley. The elevation is taken on a toothed arc, and the lateral direction is fixed by ropes and pulleys attached to eye-bolts in the rear of the chassis, as is usual; the chassis rests on semi-circular rails, whence any lateral direction may be given to the gun. The height of the gun support is ·960 meters (3·17 feet); the weight of the carriage proper is 1505 kilograms (3311 pounds) and the weight of the chassis 935 kilograms (205 pounds; the weight of the whole being 2440 kilograms (5368 pounds).

8. Finally the last naval gun upon the list is a cannon ·12 meter (4·7 inches) mounted on a sea-carriage. The weight of this gun is 1400 kilograms (3080 pounds); the preponderance of the breech 100 kilograms (220 pounds), and the bore is rifled with 18 grooves. The cast steel shell charged weighs 17·5 kilograms (38·5 pounds) and the firing charge of ordinary coarse-grained powder is 3·5 kilograms (7·7 pounds); the initial velocity under these circumstances being 450 meters (1500 feet). The carriage is upon wheels intended for use as a battery or upon the spar deck of war vessels of small tonnage. It weighs 895 kilograms (1970 pounds).

Since the Vienna Exposition, the works at Essen have projected the manufacture of three new guns of large caliber, of which the following are the details:

No.	Diam.	Weight complete.	Prepon. of breech.	Length of rifling.	Diam. of rifling.	Cst iron shell charg'd	Steel shell charg'd	Firing charge.	Elong. shell charg'd	Firing charge.
	cm.	kilos.		mm.	mm.	kilos.	kilos.	kilos.	kilos.	kilos.
1	35½	57500	——	5260	363	480	474	95	409	82
2	40	82000	——	5900	409	685	675	135	580	111
3	46	124000	——	6430	470	1040	1025	200	800	175

The length of the rifling above given, corresponds respectively to 14·82, 14·75 and 13·97 calibers. It is estimated that the first of these guns will entirely penetrate, with both the steel and the chilled iron projectiles, a plate of iron 41·85 centimeters thick (16·5 inches) upon a backing similar to that of the Bellerophon, placed at a distance of 500 meters (550 yards) or a plate of 36·6 centimeters (14·5 inches) at a distance of 2300 meters (2530 yards). The last of the guns above described is expected to be capable, with the most effective projectiles of penetrating a plate 47 centimeters (18·5 inches) thick, backed as before and placed at a distance of 2900 meters (3200 yards). Since it has already been found entirely possible to carry two guns weighing 36 tons each—72 tons in all—upon a turreted vessel, it would seem that a similar vessel of war might be constructed to carry either in a

turret or on a revolving platform, two of these largest cannons, weighing only 57 tons each. The projectiles from such a gun would destroy, even at the longest ranges, the heaviest armor at present existing upon any vessel of war. To resist these frightful missiles, plates of 61 centimeters (24 inches) in thickness would be necessary; such plates for example as the Inflexible, a ship actually in course of construction in England, will have for her armor. The above cannon of 35 centimeters diameter, with its carriage and the material necessary for 100 shots, would weigh 126·5 tons.

New Photographic Method for Observing the Transit of Venus.—The celebrated French astronomer Janssen, has recently brought before the Academy an ingenious apparatus which he had devised for ascertaining the precise instant of contact of the planet Venus with the limb of the sun on the approaching transit of the 10th of next December. The difficulty of fixing the exact time with the telescope is due, as is well known, to the formation of a black ligament uniting the two. In Janssen's apparatus, a movable disk, having toward its edge equidistant round openings, turns before a second disk covered with sensitive paper. By means of clock work, the outer disk is made to move every second over a distance equal to the diameter of one of its openings. Hence every second there is a new plate exposed, and a new picture taken. By examining each picture, it is possible to determine exactly the time of contact.

Projected Tunnel under the Simplon.—A short time ago a proposition was made in the French National Assembly to effect a loan of 48 millions of francs for the purpose of constructing a tunnel under the Simplon pass. The subject was referred to a commission, and this commission has recently reported through M. Cezanne. The great advantage offered by the Simplon route is that it shortens the distance between Paris and Plaisance (Italy) by 67 kilometers over the Mt. Cenis route. But in such a case the horizontal distance is by no means the only one to be considered; the altitude is also of great importance. In this respect, too, the Simplon route has great advantages, since it is 503 meters (1660 feet) lower than that by Mt. Cenis and 369 meters (1218 feet) lower than that of St. Gothard. Unfortunately, however, these advantages are in great part neutralized by the necessity which this route imposes, of traversing the Jura, which would require a grade of twenty to twenty-five

feet in a thousand. Indeed, the route from Paris to Milan by the Simplon would find its highest altitude—at least 1100 meters—not in the Alps, but in the Jura. Moreover in discussing this question it is often assumed that a tunnel virtually suppresses the Alps, the railway passing directly from the French to the Italian plains. But this is far from being the case. It is indeed true that on the northern side, the foot of the Simplon may be reached through the Rhone valley by a grade not heavier than fifteen feet in a thousand —though only, as just stated, after traversing the Jura at an altitude of 1000 meters by a grade of twenty to twenty-five feet. But on the southern side, the Simplon tunnel issues at least 100 meters above the plains of Italy, to reach which a grade of twenty-five feet in a thousand is necessary for a distance of twenty kilometers. These disad) vantages seem to the Commission to more than counterbalance the advantage of shorter distance between Paris and Plaisance. But another question here arises. Will the Simplon tunnel divert toward France the traffic from Belgium and northern Germany, sure without it to go to the St. Gothard tunnel, not being available for that of Mt. Cenis? A glance at the map answers this question. The Simplon is very near St. Gothard; the two tunnels would not be more than fifty kilometers apart, at their northern ends. In issuing from the St. Gothard tunnel and following the course of the Rhine, the descent is easy and without a break to Basle, Cologne, Antwerp; while in leaving the Simplon tunnel, the railway, turned westward by the high chain of the Jungfrau, is obliged to traverse the Jura, is repelled by the Vosges, checked by the Ardennes and only reaches the low lands of Belgium, Holland, and Germany with difficulty. An examination of the route by these two lines, from Basle—at the head of the great Rhine plain and easily accessible to Switzerland, Alsace, and Germany —to Milan, the point in Italy where they both unite, will strengthen much the negative answer to this question. M. Stockalper, a Swiss engineer, himself interested in the Simplon scheme, has published some important data of cost, in this connection. He finds that to transport a ton of goods from Basle to Milan by the St. Gothard tunnel would cost 21·46 francs; while by the Simplon tunnel it cannot be done for less than 23·28 francs. These considerations are conclusive with the commission; and they close their report with the following words:

"When numerous enterprises, purely French in their character, are obliged to suffer postponement for want of resources, we cannot undertake a foreign work of the magnitude of the Simplon tunnel.

France is to-day in the situation of a large landed proprietor who has seen his territory invaded, his crops destroyed, his dwellings burned. It is in vain that his interest is solicited in laying out a road through an adjoining property, while his own ruins are yet unrebuilt, and his own grounds are still unrestored."

The Light of Coggia's Comet Polarized.—Professor Wright, of Yale College, publishes in the *American Journal of Science* the results of his observations with the polariscope upon the light of Coggia's comet. During the greater portion of the time when the comet was favorably situated for observation, it was unfortunately hidden by clouds or extinguished by thick haze. On one or two occasions, however, he was able to obtain evidence that its light was polarized. The instrument made use of was the very sensitive combination with which his observations upon the zodiacal light were made. On the evening of July the 6th, although the sky was generally full of drifting clouds clear intervals appeared now and then, which allowed a distinct view of the comet. The polariscope showed the bands, both bright and dark, quite definitely, and they were seen with comparative ease. Observations repeated a number of times agreed in showing that the light was polarized in a plane passing through the axis of the tail; that is, as nearly as could be estimated, in a plane passing through it and the sun. Other observations made on the evening of July 14th, when the sky was quite clear, gave the same result, though less satisfactorily, as the twilight had begun to interfere with the observations. After waiting until this had disappeared, it was possible to see the bands, though with some difficulty, and the degree of the polarization appeared to be decidedly less than on the previous occasion. The percentage of light thus polarized could not be accurately fixed, but it was not large. The conclusion is therefore that a considerable portion of the light of the coma is derived from the sun by reflection.

Impermeable Paper.—By plunging a sheet of paper into an ammoniacal solution of copper for an instant, then passing it between the cylinders and drying it, it is rendered entirely impermeable to water, and may even be boiled in water without disintegrating. Two three, or any number of sheets thus rolled together become permanently adherent, and form a material having the strength of wood. By the interposition of cloth or of any kind of fiber between the layers, the strength is vastly increased.

Meteoric Occlusion of Hydrogen.—In a paper read at the recent meeting of the American Association at Hartford, upon the use of iron tubes, externally glazed, for nitrogen determinations, by Professor A. P. S. Stuart, the author showed that the hydrogen of the coal gas employed for the combustion, passed freely through an unglazed tube at a high temperature. Since the hydrogen previously occluded by iron meteorites, would be discharged again by the high temperature caused by ignition in our atmosphere, were this ignition to take place throughout their mass, Professor Stuart suggested the hypothesis that the hydrogen which they contain was occluded on striking the moist earth; the incandescent mass first decomposing the water in the soil, and then occluding the evolved hydrogen. In the discussion which followed, Dr. Lawrence Smith inclined to the hypothesis, that the heating of a meteorite in our atmosphere was merely superficial, and that therefore, the occluded hydrogen in its interior was retained.

The St. Gothard Tunnel.—On the 30th of June last, according to the monthly report of the Federal Council, the St. Gothard tunnel had pierced the mountain to a depth of 1956·8 meters (6418·3 feet); nearly one-seventh of the entire distance, which is 14920 meters (48937·6 feet). During the month of June the advance was 133·4 meters, of which 70·3 meters was on the Gœschenen side, and 63·1 on the Airolo side. The enlargement of the tunnel was carried on through a distance of 1362·4 meters. The mean number of workmen employed has been 1744; the maximum number 2076. On the Gœschenen side, the tunnel traversed a granitic gneiss, intersecting at the 999th meter a quartz pocket two meters long. The rock was in general quite dry, although occasional talcose fissures occurred, in which there was moisture. At the heading, six Ferroux drills are in operation, the average daily progress being 2·342 meters. For trimming, the machines of Dubois, Francois, Sommeiller and McKean are in use; beside these, hand-drills are also used. On the Airolo side, the tunnel has traversed a quartzose garnet-bearing mica schist, intercalated with hornblende schist and massive hornblende. Many fissures were met, from which water issued, at a temperature of 10·7° to 11·3°C. The rock itself, however, was quite dry. The drills used were those of Dubois and Francois, and latterly the improved drill of McKean. The mean progress at this end has been 2·1 meters per day. The trimming and enlargement has been effected by eight Sommeiller machines.

Editorial Correspondence.

Gohlis, Leipzig, March 20, 1874.

To the Secretary of the Franklin Institute;

Dear Sir: I beg leave to inform you of a novelty in Mechanical Engineering, a description of which you will find in the annexed paper. As this invention has created quite a stir among our best engineers, I trust that you also will take some interest in it. Yours Respectfully,

W. E. ABLAND.

A Petroleum Motor.

For a number of years, the tendency among Mechanical Engineers has been to substitute a cheaper and more convenient motor, for the always expensive Steam Engine, especially in those establishments that require a comparatively small working-power. This tendency has originated a new machine in addition to various engines of more recent notoriety (such as the Lenoir Gas Engine, the Lehmann's hot-air Machine, the Siemens' Motor and others) to which the name Petroleum Motor has been given.

Referring to the accompanying cut, Figure 1, we will explain the principle of this new machine, which has so largely attracted the attention of Engineering circles; inasmuch, however, as we

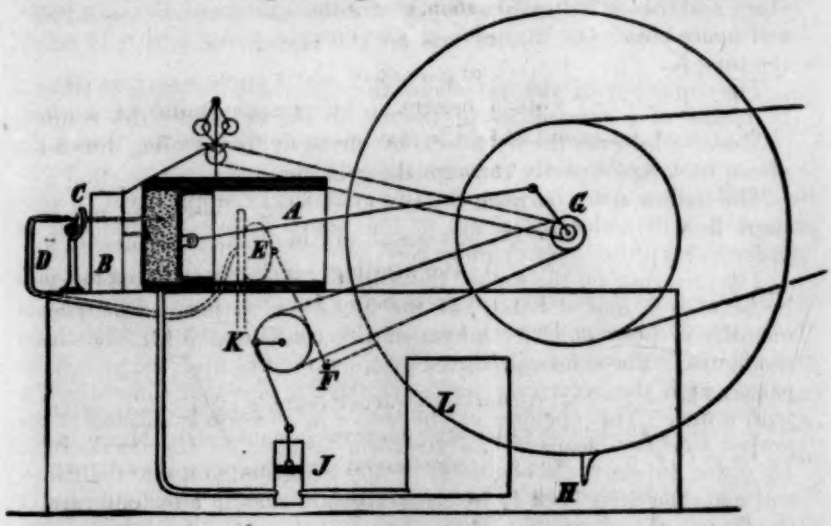


FIG. 1.

are just about to secure a patent, we shall reserve for the present, minute explanation of the more important details. But we will

promise in a later description, to give such explanations accompanied with all the required cuts.

The principle of the Petroleum Motor is similar to that of the ordinary single acting horizontal steam engine, except that while the expansion of steam is employed in the latter, a quantity of petroleum converted into vapor is applied in the former to move the piston.

The double cylinder A, Fig. 1, contains at the bottom three valves, the middle one being provided with a nozzle covered with wire gauze. Through this the petroleum supplied from the vessel B, is forced or injected into the cylinder as a fine spray.

The second valve, above the one just mentioned, serves to allow a flame C, to come at the proper moment, in contact with the finely scattered petroleum which has entered through the said middle valve, and thus to cause its explosion. This flame C is driven through the second valve into the cylinder at short and sudden intervals, by a strong draft of air. When the explosion takes place, both valves, which open inwards, shut immediately, and the piston is driven forward. This piston is hollow, and to an inner partition the piston-rod is attached by means of a hinge and bolt, while the piston-rod itself is in direct connection with the crank G, to the axle of which, both the belt-pulley and fly-wheel are fastened. A projection H is fixed to the rim of the latter, in the form of an elongated cam or toe, pressing, at every revolution of the fly-wheel upon an air cushion E, thus effecting a flow of air through the pipe D. When the air reaches the flame in front of the valve, it causes a jet similar to that produced by a blow-pipe; and this as indicated above, causes the ignition of the petroleum, and hence effects the explosion. The cushion is supplied with air by the pipe K.

The injection of the petroleum through the wire gauze is effected by means of a rarefaction of the air in the cylinder; this result is produced whenever the fly-wheel, by virtue of its vis viva, draws the piston back again partly through the cylinder.

The hollow space between the two cylinders is supplied with a constant flow of water, by means of the pump J, from the tank L, in order to keep the inner cylinder cool.

The governor on the top of the cylinder, whose motion is generated by bevel-gear and a band, has for its object to procure the proper quantity of petroleum by means of the compound lever shown in the figure. The smoke produced by the combustion of the petroleum passes, with the returning piston, through a pipe that communicates with a flue. The opening of the valve in question is effected at the proper time, by means of an eccentric fastened to the crank-shaft. In order to start the engine, it is only necessary to ignite the flame, and open the stop cock to let the petroleum rush in after one turn of the fly-wheel.

The firm, "Wiener Eisen und Maschinen-fabriks Actien Gesellschaft," in Vienna, where the Petroleum Motor is at present made, claims the following advantages over other similar Engines.

1. Perfect safety; neither incompetence or malice can cause a destructive explosion.
2. No particular attention needs to be given to the engine.
3. The facility with which the engine can be started and stopped; no complex preparations being necessary.
4. Its almost noiseless operation.

To these may be added economy of space, as no boiler or heating apparatus is required; and the cheapness of the Petroleum Motor itself.

The Petroleum Motor is built from 1 to 3 horse power, and the consumption of petroleum for a 1¼ horse power engine amounts to about 6 cents per hour.

Bibliographical Notices.

THE MANCHESTER STEAM USERS ASSOCIATION FOR THE PREVENTION OF STEAM BOILER EXPLOSIONS. *Chief Engineer's Report for January, February, March and April,* 1874,—*and Proceedings of the annual meeting of the Association, held March 24th,* 1874.

These Reports are both able and thorough, and contain much that commends itself to steam users in this country.

Beside an abstract from the record of inspections and an enumeration of the defects thereby discovered, there is a tabular statement of all the explosions which have occured in the district, giving the class or style of Boilers; the character of service; the nature of rents and other effects of the explosion; the verdict of the Inquest, and the number of persons killed and injured.

In some of the more important of these disasters, the Engineer of the Association was called as an expert witness before the Inquest, and has entered very largely into details, giving drawings of the Boilers, both before and after these explosions.

The thoroughness with which this work has been done, is only possible under such an organization as this, and it is just here that Americans should profit by their experience.

The policy of the Association is not to make dividends; but, believing in the absolute prevention of Boiler explosions, it uses the whole of the funds received from its members, exclusively for the good of these members, first by securing a careful inspection and supervision of their Boilers, and second by making careful scientific investigation

into the causes of explosions, and the methods of their prevention, and by disseminating information in relation to economy of fuel, and proper management of Engines.

Nor are they niggardly in spreading the knowledge thus acquired, for they communicate it freely to the public press, and to the corresponding members in other parts of the world.

The value of this policy to the members, may be estimated from the fact, that during the nineteen years of the existence of the Association, no explosion of a boiler under its charge has occurred, while during only the four months covered by the report, there occurred in the same district, fourteen explosions of steam Boilers, killing thirty-six persons and injuring seventy-three others.

If then, this policy is productive of such excellent results, how much better it is than any simple insurance against the damage done to property by these explosions, leaving the much greater loss, that of life, entirely unprovided for, and leaving the insured in greater darkness as to causes and prevention, than before.

Whatever views may be entertained on all other points in reference to these subjects, we say, give us by all means, such thorough investigations as these; investigations by competent men who are in no wise dependent on, or influenced by the profit side of the accounts; and then spread broadcast the information thus obtained. K.

AN ELEMENTARY TREATISE ON STEAM. By JOHN PERRY, B. E., *Whitworth Scholar; Fellow of the Chemical Society; Lecturer in Physics at Clifton College.* 18 mo., pp. xii., 412. London, 1874. Macmillan & Co.

This little book of Mr. Perry's makes no pretension to exhaustiveness of treatment or to originality of fact. In his preface he acknowledges his indebtedness to the recognized authorities on the Steam-engine and offers the book simply as a text-book to those students who have but little Algebraical and Trigonometrical knowledge, and are acquainted with the simpler facts in Physics. The subject is treated in four books. Book I, considers the principles of Heat; Book II, Steam-engines and boilers: Book III, Locomotives; and Book IV, Marine-engines. These books are very minutely subdivided into chapters, of which the book contains forty-five; thus affording a pretty complete classification. To those chapters admitting of it, a valuable set of problems is appended, thus giving the student opportunity to test his knowledge at every step of his progress. We believe, however, he has attempted to treat too many subjects in too small a compass. Some of the chapters, as for example, the last one on Locomotives, which is on "Permanent Way," and which is a very extensive subject of itself, might with advantage, be omitted and its space be allotted to amplification in other directions; as for instance, in that of Compound engines. We doubt not this little book will be of essential service to students and we commend it to their notice.

rformances of the Steam Machinery under conditions of substantially uniform operation, at sea.

	Speed.	Average Revolutions per Minute.	Indicated Horse Power.	Coal per Hour.		Coal per Indicated Horse Power per Hour.	Variety of Coal.	Concentration of Water in Boiler.	Ashes per Hour.	Barometer.	TEMPERATURES.					
				By Account.	Actual, by Bunker Meas'ments.						AIR.			WATER.		
											On Deck.	Engine Room.	Fire Room.	Sea.	Disch.	Hot Well.
	Knots.			Lbs.	Lbs.	Lbs.		32ds.	Lbs.	Ins.	Degs.	Degs.	Degs.	Degs.	Degs.	Degs.
lit-on	6·96	61·440	112·35	224·90	238·39	2·122		1·37	61·73	29·88	79·3	108·0	100·6	82·0	102·0	132·6
cea-sea.	6·41	64·012	126·42	224·10	237·44	1·878		1·41	40·00	30·07	84·2	109·5	106·9	85·6	103·9	139·7
lat-ard	6·28	65·080	152·85	276·89	293·41	1·920	Cardiff.	1·26	60·00	30·04	64·3	94·8	91·6	67·7	98·1	140·0
	7·34	65·305	138·70	224·00	237·44	1·712		1·58	40·00	29·63	——	93·4	89·0	66·2	100·0	135·0
	6·55	68·113	171·32	280·00	296·80	1·732		1·55	61·66	30·05	——	89·6	91·2	64·8	96·5	140·0

Mean 1·87.

Civil and Mechanical Engineering.

PERFORMANCE OF THE COMPOUND ENGINES OF THE U. S. COAST SURVEY STEAMER "HASSLER."

By CHARLES E. EMERY, Consulting Engineer.

[TO THE EDITOR OF THE JOURNAL OF THE FRANKLIN INSTITUTE:—

DEAR SIR: By permission of Capt. C. P. Patterson, Superintendent of the U. S. Coast Survey, I forward, for publication, the following extracts from a report made to him by myself, as Consulting Engineer U. S. C. S., on the subject above indicated. The facts mentioned are of special interest, as the engine of the Hassler is believed to be the first built in this country to secure special economy for marine purposes, and was designed independently of the English practice and in fact in anticipation somewhat of the revival here of interest in Compound Engines. It will be observed too that special pains were taken to ascertain accurately the facts in regard to the performance. The report is dated November 1st, 1873. C. E. E.]

I transmit herewith an abstract of the Engineer's Journal of the U. S. Coast Survey Steamer "Hassler," with tabulated results founded thereon, showing the performance of the steam machinery, at sea, under conditions substantially uniform, but, on the whole, more unfavorable than in ordinary practice.

The abstract is made from the record of the run from Panama to San Francisco in July and August of last year (1872) that being the first time, after the engineers were furnished with complete blank journals and careful instructions suggested by former experiences, that the vessel was under steam for a sufficient period to furnish reliable information.

The steamer had just come from the Atlantic Coast, consequently some matters were out of repair: for instance a defective stuffing-box caused a poor vacuum, and a leaky tube in the condenser required the use of some salt water; both faults reducing the economy. So also the iron bottom of the vessel was very foul, which reduced the speed.

The steaming for the time included in the abstract, was made at half boiler power, which should have given, with clean bottom, an average speed of 7½ to 8 knots, under the conditions encountered.

Runs.				Steam Pressure.		Cut off per Indicator.	Throttle	Vacuum.	
No.	Directions.	Date.	Duration.	In Boiler.	In Cylinder.				
		1872 Inclusive.		Lbs.	Lbs.	Prop.		Ins.	
A	Panama to Tartar Shoal	July 24 to 31	180 hours or 7½ days.	68·11	62·93	·32	Wide Open.	23·30	Most o tle sail t fifth and
B	Acapulco to Magdalena Bay	Aug. 7 to 12	114 hours or 4¾ days.	76·51	71·20	·31		19·64	Light sionally
C	Magdalena Bay to San Diego	Aug. 15 to 17	72 hours or 3 days.	77·76	75·66	·41		16·08	Vessel r Head ter part bow.
D	San Diego, at sea, and return	Aug. 25	20 hours	76·00	69·00	·35		22·75	Maina
E	San Diego to San Francisco	Aug. 29 to 30	35·03 hours.	78·53	70·00	·47		19·16	Light

Survey Steamer "Hassler," with calculations, showing the performances of the Steam Machinery under conditions of substantially

Vacuum.	Wind and Sea. Sail.	Speed.	Average Revolutions per Minute.	Indicated Horse Power.	Coal per Hour	
					By Account.	Act by B Meas'
ns.		Knots.			Lbs.	L
3·30	Most of the time light variable winds, permitting a little sail to be set. Sea smooth except for a short time on fifth and sixth days.	6·96	61·440	112·35	224·90	238
9·64	Light variable winds and smooth sea, with sail set occasionally for 3½ days. Last 24 hours headwind and sea. Vessel making slow progress.	6·41	64·012	126·42	224·10	237
3·08	Headwinds and sea early part of run. Light winds latter part. Some sail set. Light wind and sea on starboard bow.	6·28	65·080	152·85	276·89	293
2·75	Mainsail and jib set part of the time.	7·34	65·305	138·70	224·00	237
9·16	Light head wind. No sail.	6·55	68·113	171·32	280·00	296

Stops were made in various ports and for sounding and dredging purposes during the trip, so the abstract has been divided into five runs, designated by letters, during each of which the conditions were substantially uniform and the steaming continuous, except one stop for dredging in each of the two first; in these the whole watch of four hours, in which the stop was made, has been rejected, to secure the condition of uniform operation. The other columns will be understood from the headings. Following the abstract I give a brief discussion of portions of the same with references to other performances of the vessel. I also append for reference a short description of the vessel and machinery.

The following extracts from the instructions printed in the Engineer's Journal will show the precautions taken to obtain accurately the power developed and its cost in fuel:

"The steam pressures, vacuum, and positions of throttle and cut-off, as recorded, should be the means for the hours, and not simply correct records at the time of the observation. In case that by order or accident, the average conditions are abruptly changed during the hour, interlined entries should be made showing the average for each period, and the exact time of the change be noted in the remarks.

A complete set of indicator-diagrams should be taken at least once every day: for instance, shortly before meridian, at which time the position of the cut-off, throttle, and the steam pressure and other conditions should be regulated so as to represent, as nearly as possible, the average for the steaming done during the previous 24 hours. The diagrams necessary for a complete set should all be taken as nearly as possible at the same time, and the data provided for in the specimen diagram herein be collected and noted without delay. The diagrams and data should show the facts as they exist at the time; the object not being to obtain a maximum result or fair looking diagrams. The original diagram should be slightly secured with mucilage at its upper left hand corner, between the pages of corresponding date in the original journal. When experimenting, diagrams should be taken half hourly, in which case the name of the vessel and the date and time need only be noted thereon, and the other quantities can be obtained from the Journal.

The reading of the engine-counter should be taken exactly at the end of the hour by observing the second hand of the clock in connection with the other hands.

The *net* amount of coal used should always be entered in the log.

To check errors, the bunkers should be carefully measured when empty and drawn to scale, and after every fifteen days steaming, and just before coal is received, the coal in the bunkers should be trimmed to regular slopes, the amount measured and calculated, and the coal account corrected by an additional entry under the daily balance, as follows: 'Remaining as per measurement this day ——— pounds.' The plan of adding a percentage to each day's expenditure, or of charging for ship's use extraordinarily large amounts, is disapproved. The log should in all respects show facts as accurately as they can be ascertained; hence every deficiency or surplus should be recorded as soon as it is discovered, and the account adjusted at once."

During a previous voyage, the Commander of the vessel, to satisfy himself as to the accuracy of the coal account, had issued an order that the bunker doors be locked and opened only once in the watch in the presence of the engineer, when the coal for a watch was to be measured out. This system was productive of such good results that it was continued in connection with periodical measurements of the bunkers. Such measurement was made August 6th and again August 21st, and a deficiency in the coal account found amounting to 6·008 per cent., which could be easily accounted for by the few lumps that fell on the floor in measuring the buckets. This percentage was in later trials much reduced; but, not to overstate results, the amounts in column marked "Coal per hour by Journal" have been increased six per cent., and the augmented or actual amounts, recorded in the next column, have been used in the final determination of the cost of the power.

The above shows that, even with a comparatively small compound engine of good construction, each indicated horse power can be obtained, on regular duty at sea, for $1\frac{3}{8}$ pounds of coal per hour, or less than half that required with ordinary marine machinery of the old type, and hardly two-thirds that used, according to best testimony available, in the better class of large, direct-exhausting marine engines, using high pressure steam.

This cannot be called an experimental result. In fact the unfavorable conditions mentioned prevented it from being the maximum for regular sea duty. There is every reason to believe that, with careful attention, and both boilers in use, a result could have been obtained of $1\frac{1}{4}$ pounds of coal per horse power per hour. In fact some previous runs show this performance, but as they were made before the coal account was checked regularly by the bunker measurement, the

results are not given in detail. There is, however, no reason to doubt their accuracy.

The vessel, on her trial trip, using Schuylkill coal and both boilers, developed 125 horse power with 250 pounds of coal per hour, a performance of two pounds of coal per horse power per hour, when the boiler and engines were not felted and the weather quite cold. The firemen, too, were not accustomed to the slow combustion obtained by using two boilers, and much watchfulness was required to ensure regulation by the dampers instead of by opening furnace doors. This difficulty caused a very great waste of fuel, afterward, when it was attempted to run moderately with both boilers on regular duty at sea, and finally it was actually found, in practice, that unless an engineer was kept constantly in the fire-room, it was far more economical to *force the fires* under one boiler at slow speeds than to use slow combustion in two boilers.*

Only one boiler was in use during the runs set forth in the foregoing abstract.

The following extracts, from the official report of Commander P. C. Johnson, U. S. N., commanding the Hassler, to yourself, may, I think, be considered in place in this report:

"It gives me pleasure to request your notice of the consumption of coal while engaged in such work as the Hassler was designed for. At San Diego, before starting the fires, the ship had in her bunkers 101·09 tons.

Today on hand	68·30	"
Deduct for distilling water, galley, stoves, etc., . .	3·60	"
Showing a consumption in 35 days of . . .	29·19	"
Averaging per day	0·83	"

The ship has been under steam every moment since leaving San Diego. Excepting Sundays she has been underway during the day, and banked fires at night, having steamed 1069 miles, and made 704,026 revolutions. The bunker doors are closed and locked at all times, (except when in the act of getting out coal) and the key always in possession of the engineer. Besides weighing, the bunkers are frequently examined and their contents measured."

In a subsequent letter, Commander Johnson writes: "We have been 58 days under steam, running from daylight till dark, generally. Banked fires at night and Sundays, and have consumed in the fur-

* An attempt is being made, however, to secure the economy due to increased heat-absorbing surface by using both boilers and reducing the grate surface with fire brick. So far it has been found that the steam can be carried more steadily, but no accurate determination can yet be given in regard to the question of economy.

naces only 1891·4 lbs of coal per 24 hours —0·844 tons per day.

There is no mistake about it. There has been no stealing of coal. The bunker doors were locked except when serving out, and the measurement shows the proper amount on hand now."

I submit that the above facts are sufficient to show conclusively the great economy which may be obtained by the use of the compound engine.

For convenience of reference, a general description of the Hassler is hereto annexed.

General Description of the U. S. Coast Survey Steamer Hassler.

The Hassler is an iron screw propeller of 350 tons burthen O. M. She was built at Philadelphia, in the year 1871, and is 151 feet long on load line, and has 24½ feet breadth of beam, and 10 feet depth of hold. Her rig is that of a three masted schooner, with lower masts of moderate length and tall top masts. The officers' quarters are on deck and are very commodious.

The vessel is propelled by a compound engine of 200 horse power. The cylinders are 18·1 and 28 inches in diameter, by 26 inches stroke, and are arranged one above the other, in the same line, with both pistons on the same rod, and operating the crank through a single connecting rod. The steam chests extend beyond the ends of the cylinders to reduce the length of the cylinder ports; but for simplicity of construction, the valve face of the upper cylinder is brought out in line with the other, and the valves of both cylinders are operated by the same rods. The upper cylinder is supported from the framing by four wrought-iron columns, and the two cylinders are sufficiently separated to allow the cover of the lower cylinder to be raised to obtain access to the piston. The bed plate is made of sufficient length to receive three bearings, in addition to which an independent thrust-bearing is connected to the same. The surface condenser is arranged under one side of the frames, and slants inward at the same angle as the latter. The circulation is performed by a centrifugal pump driven directly by a small engine. The air and feed pumps are vertical, and receive motion from the main crosshead through beams in the usual way. The necessary valves are provided, so that live steam can be excluded from the upper cylinder, and supplied direct to the larger one if desired. Ordinarily the steam passes to the upper cylinder, in which it is cut off at such point as to give the power desired, or usually

at less than half stroke. The steam then passes to a large reservoir, placed under the main deck, through which it traverses slowly, thus permitting the water due to condensation for the work done, to become separated. From this reservoir the steam passes to the lower cylinder, but the supply is suppressed therein at such point as to keep the pressure in the reservoir substantially uniform. The lower cylinder communicates with the condenser in the usual way. The large cylinder and its bottom and head are steam jacketed. Drip vessels with glass gauges are provided to assist in blowing the condensed water from the jacket and reservoir. The propeller is a true screw, 8 feet 6 inches in diameter, with 13 feet pitch. At the hub the blades are rounded on both sides to reduce the resistance where the metal is thickest. The flat propelling surface gradually widens from the hub outward to 4 feet diameter, and the outer portions of the blades are of the ordinary construction.

Steam is supplied by two flue and return tubular boilers, each 6 feet in diameter and 12 feet long, and provided with a steam chimney. The total grate surface is 42 square feet, and the total heating surface 1400 square feet.

The shells are $\frac{5}{8}$ inch thick, with double riveted longitudinal seams. All flat surfaces are stayed 6 inches between centres. The boilers are considered of sufficient strength to carry regularly 80 pounds pressure for a series of years.

The maximum speed of the vessel, under steam alone, is $9\frac{1}{2}$ knots. Under steam and sail, she has made easily 10 and 11 knots. The ordinary speed at sea, under steam alone, is restricted by order to 8 knots, which can be obtained with one boiler under favorable circumstances.*

* It will be of interest to add, in this connection, that the first reports as to the performance of the "Hassler" were unsatisfactory, owing to very bad management in the Engineer Department. The vessel left the Atlantic Coast in the fall of 1871, and as her commander found it necessary to take coal much sooner than was expected from results obtained on the trial trip, he instituted an investigation which had the effect, eventually, to make the performance all that could be desired, and to interest all on board in the matter, so that in fact a number of naval officers, then attached to the vessel, but who have recently returned to the East, have expressed a desire that the actual facts, as to the vessel's later performances, should be made public.

EXPERIMENTAL DETERMINATION OF THE CENTRE OF GRAVITY OF THE UNITED STATES STEAMER "SHAWMUT."*

By T. D. Wilson, Naval Constructor, U. S. N.

Naval Constructor's Office, Navy Yard, Washington,
May 8th, 1874.

To the Hon. Geo. M. Robeson, Secretary of the Navy:

Sir: In accordance with circular from the Navy Department, under date of March 17th, 1874, I have the honor to respectfully submit a report of an experiment made by me on the U. S. Steamer "Shawmut" the day before she sailed for Key West, for the purpose of ascertaining the height of her centre of gravity.

At the time this experiment was made the "Shawmut" was lying in the Potomac River, below the Navy Yard, Washington, D. C.

Although the wind blew a little fresh, there was no sea on, thus enabling the draught of water to be taken very correctly.

The ship was complete in every respect and ready for sea; the topsail yards were on the caps, sails all furled, boats hoisted, and the two broadside nine inch guns run out; the eleven inch pivot on the main deck, and the 20 pounder pivot gun on topgallant forecastle, were amidships and secured for sea.

She had on board a crew of about one hundred men, with provisions for the full complement for three months—32,295 pounds of water in casks and tanks, 208,320 pounds of coal in the bunkers, both boilers full of water, and steam up, the weight of water in the boilers being 53,000 pounds.

The estimated weight of the articles on board, coming under the Department of Equipment and Recruiting, excepting coal, was 108,160 pounds; the two lower anchors weighing 6,170 pounds, were down when the experiment was made. The total weight of ordnance, ordnance stores and equipments, was 117,113 pounds. Total weight of

[* The following report to the U. S. Navy Department describing the experimental determination of the position of the centre of gravity of the U. S. S. Shawmut, has been kindly furnished us for publication. The officer who has signed this report is a well known naval constructor, and the author of a standard work on naval architecture used at the Naval Academy. The report is valuable as giving very clearly and concisely the method of performing an important but seldom practised manœuvre—one, however, which should always form a part of the preparation of a vessel for service. The loss of H. B. M. ironclad "Captain," in consequence of the neglect of the Admiralty to determine the curve of stability of that vessel, was a warning which was not unheeded in Great Britain, and we may presume that it was understood by our own Navy Department. This report is transmitted to us by Professor Thurston, of the Stevens Institute of Technology, to whose collections its author had contributed a copy. Ed.]

engineers' stores and spare machinery 4,000 pounds. Total weight of carpenter's stores 7,068 pounds.

The conclusion that it would not be necessary to employ any other means to incline the ship, than that of shifting her guns, was arrived at with great satisfaction, on account of the great objection to having a large quantity of rusty pig iron upon the clean deck of a vessel in commission, the expense attendant on transporting it to and from the yard, and also because of the still further departure from the normal state of the ship which its presence would produce, and the necessity for still greater complexity in the calculations.

As this experiment was made for my own gratification, it was necessary that the consent of the commanding officer, Commander Henry L. Howison should be first obtained, which was freely given, and all the assistance he could afford was cheerfully accorded, for which, to him and his Executive Officer, Lieutenant Commander Norris, I am greatly indebted.

As this is the only instance that I know of, where a U. S. Naval vessel has been experimented upon for this purpose (with the exception of the U. S. Steamer "Princeton," and Brig "Somers," which were inclined by Naval Constructor John Lenthall, late Chief Naval Constructor U. S. N., at the Navy Yard, Philadelphia, in 1844, an account of was recorded in the *Franklin Institute Journal;* the "Princeton" was inclined by moving weights on her decks, the "Somers" by hanging weights on her lower yard arms) I consider it necessary, in order that the subsequent portion of my report may be better understood, that I give a *rationale* of the experiment, which may be found recorded in the *Transactions of the Institution of Naval*

Architects for 1860, as made by F. K. Barnes, Esq., member of the Council of Construction, H. B. M. N. Let A C D figure 1, repre-

sent the transverse section of a ship, through G the common centre of gravity of the hull, and every article on board; W L the load water line when the ship is floating in upright position; CBGM the middle line which is, therefore, perpendicular to WL, and also contains G, the centre of gravity of the ship, and B the centre of buoyancy (or centre of gravity of the displacement). Let also P represent a weight or weights on any or all of the decks, such as guns, shot, ballast, etc., capable of being readily transported to the opposite side of the deck or decks.

If the weight or weights P be moved across the deck to P′ the ship will incline through an angle W S W′, the amplitude of which will depend, *cæteris paribus*, upon the weight or weights moved, and the distance through which they have been moved.

When the ship has taken up the new position of equilibrium, the centre of buoyancy will have moved from B to B′, and the centre of gravity of the ship from G to G′, so that the line joining B′ and G′ will be vertical, and, therefore, perpendicular to W′ L′, the new water line, and will make the same angle B M B′ with the middle line B G M, as the water lines do with each other, and B′ G′ produced will meet in the middle line in a point M.

This point, in ships of the usual form, may, without any appreciable error, be assumed to coincide with the *metacentre* when the inclination does not exceed 4° or 5°.

From a general and well known property of the centre of gravity of a system of bodies, such as a ship, we know that since the weight or weights P have been moved in a horizontal direction to P′, the centre of gravity has also moved in the same direction; therefore G G′, the line joining the original and new centre of gravity, will be horizontal; and from another property of the centre of gravity we have that the weight of the ship $\times$ G G′ = P $\times$ distance through which it has been moved; or if W represent the total weight of the ship, and c the distance through which the centre of gravity of the weight or weights P has been moved,

$$W \times G\ G' = P c.$$

and

$$G\ G' = \frac{P c}{W}$$

Now by trigonometry G G′ = G M $\times$ tangent of the angle between the middle and the new vertical line B′ G′ M, i.e., the angle of the ship's inclination from the upright; or representing the angle of inclination

by φ

$$G\,G' = G\,M \tan \varphi$$

$$G\,M = \frac{G\,G'}{\tan \varphi}$$

Equating the two values of G G′ thus obtained

$$\frac{Pc}{W} = G\,M \tan \varphi$$

or

$$G\,M = \frac{Pc}{W \tan \varphi}$$

The right hand member of this equation contains all known quantities after the ship has been inclined, and since the *metacentre* corresponding to any draught of water is easily obtained by calculation from the drawings of the ship, and its position fixed, the distance GM set off below it will give the position of the centre of gravity of the ship.

Finally the angle of inclination (φ) is found with the greatest exactness in the following manner:—

A T-square above twenty feet in length, with a wide, thick blade is nailed to the combings in the hatchways in a vertical direction, one in the main and one in the fore hatch. The two squares being independent of each other are intended to serve as mutual checks, and also to point out any racking of the ship, which might be occasioned by the movements of the weights on board.

From the upper edge of the head of the square, a distance of 20 feet is carefully set off upwards, and at the height thus obtained, a nail is driven into the board, and to it is attached a plumb line, the plummet hanging freely at some distance below the head of the square.

When the vessel is upright, and the experiment about to be commenced, the point where the plumb line intersects the upper edge of the head of the square is carefully marked; and when the ship has obtained her new position of equilibrium by the movements of the weights, the new point of intersection of the plumb line and the upper edge of the head of the square is marked in like manner. The distance in feet between the two points marked on the square, divided by twenty, will clearly give the tangent of the angle of the ship's inclination. The first thing done in commencing the experiment was to go to quarters; the powder division having been called on deck, the crew were divided equally on either side of the deck in single file, and along the edge of a seam in the deck, equidistant from the centre; the marines being divided and placed in a similar manner on the poop deck.

The two T squares having been fixed in position, and the draught of water noted, the men were cautioned to note their position so that they could resume it again when ordered to do so.

When all were again quiet, and the ship steady, the points in which the plumb lines crossed the upper edges of the squares were carefully marked as already described; an operation which occupied scarcely half a minute, and it is only during these short intervals, when the marks are being made, that the men need be under any constraint.

The men were then ordered to transport the nine inch gun from the port to the starboard side of the deck, placing it fore and aft the deck, as far out as it could be got, and close to the nine inch gun on that side. The nine inch pivot gun was then swung around to starboard and run out. The 20 pounder rifle on the topgallant forecastle was also swung around to starboard and run out; after all the guns had been moved the men were ordered to resume their stations as before directed. As soon as all were again quiet, the points in which the plumb lines crossed the upper edge of the T squares were marked at the same time; and the deflection of the plumb line, read off from both squares, was found to be sixteen inches.

The work of the crew here terminated, and by the movement of the guns above mentioned, a registered inclination was obtained, and data furnished, by which the centre of gravity might be found.

The weight of each gun moved was taken, and the distance through which it had been moved in a transverse direction, was then very carefully measured and recorded.

Thus ended the work on board the ship; the recorded draught of water at the lines of the above experiment was, forward 11 feet 0 inches, aft 13 feet 6 inches.

Displacement to the above line in tons 1010·84. Centre of buoyancy below water line 4 feet 6 inches. Centre of buoyancy above the lower edge of the keel 7 feet 6 inches. Metacentre above centre of buoyancy 7 feet 5½ inches. Metacentre above lower edge of the keel 14 feet 11½ inches.

The sum of the products of each weight, and the distance through which it was moved, was (in tons and feet) 199·32, and the deflection from the upright of the plumb lines in 20 feet was 16 inches; denoting by φ the corresponding angle, $\tan \varphi = \frac{1\frac{1}{3}}{20} = \frac{1}{15}$, $\varphi = 3^\circ\ 49'\ 21''$.

Weight of nine inch gun and carriage 10,437 pounds, moved 20·66 feet. Weight of eleven inch gun and carriage 24,159 pounds, moved 7 feet. Weight of 20 pounder rifle and carriage 3,793 pounds, moved 3·665 feet.

$G\,M = \frac{Pe}{W \tan \varphi} = \frac{199{\cdot}32 \times 15}{1010{\cdot}84} = 2{\cdot}958$ feet, centre of gravity below metacentre. The height of the centre of gravity above the lower edge of the keel 14·95 feet—2·96 feet = 11·99 feet. The height of the centre of gravity below the mean load line is, therefore, ·26 = 3¼″. Relative stability or displacement, multiplied by the distance between the metacentre and centre of gravity 1010·84 × 2·96 = 2992·0864

The first instance in which this experiment was tried, to determine the position of the centre of gravity of a ship, experimentally, was on board H. B. M. Sloop "Scylla" and the "Rover," of eighteen guns, in Portsmouth harbor in May 1830. The experiment was made by a Mr. Morgan, of the School of Naval Architects, at that time the foreman of the Portsmouth dock yard.

No other experiments are recorded from that time up to 1855 (excepting those made on the "Princeton" and "Somers," before mentioned, in 1838, and found recorded in the *Franklin Institute Journal*) when by the upsetting of the Steam Transport "Perseverance" in the dock at Woolwich dock yard, the subject was brought under the serious consideration of Naval Architects. The determination of the metacentre and centre of gravity, is now made for every ship added to the English Navy.

The labors of Mr. Froude, and of other gentlemen who have devoted their attention to the subject of rolling of ships, has resulted in the establishment of two great facts. The first of these is that the principal thing (although not the only one) which influences rolling, is the distance between the centre of gravity of a ship, and the *metacentre;* the second is, that a ship rolling at sea is largely influenced by the period, etc., of the waves she meets with. Experience confirms the accuracy of both of these deductions.

Ships which have a great distance between the centre of gravity and metacentre are technically termed "stiff," and will spread a great amount of canvas, but they usually roll with violence.

On the other hand, ships which have a moderate distance between these points are not so "stiff," and roll moderately; while if the distance is very short, she will be "crank," and might, possibly, under some circumstances, be upset.

* * * * * * * * * * *

Very Respectfully

Your Obedient Servant,

(Signed) T. D. Wilson, Naval Constructor, U. S. Navy.

THE THEORY OF AERO-STEAM ENGINES.

By J. A. Henderson, M. E.

[Continued from vol. lxviii., page 25.]

Before making any numerical calculations, the following general formulæ applicable to such an engine and boiler are introduced as embracing the main points of importance or of interest, and as serving for a common basis from which the several examples may be worked out by direct substitution.

The principal authority referred to for the constants used in calculation was Professor Rankine; and his nomenclature and fundamental equations were applied when practicable. The majority of the formulæ, however, and more especially those relating to the determination of the proportions of steam and air, by weight, and by volume before mixture, their tensions when mixed, and to the determination of the value of the constant γ for the mixture, were here deduced by the writer to meet the wants of the occasion, as no such formulæ could be found in published works.

All of the formulæ, other than those whose results are ratios, apply to such quantities as are produced by the entrance of one pound of air through the compressing pump, this mode of treatment greatly simplifying the relations between them.

The general method adopted for obtaining the effective work developed per pound of air admitted, by computing the work of expansion and compression from the theoretic forms of the diagrams, and taking the difference, was found to be the most satisfactory and direct under the circumstances.

It should be observed that the word *air*, owing to its shortness, is commonly employed to denote the *products of combustion*, except, of course, in those statements where the use of the more specific term becomes necessary.

Below is given the general notation to be used in the formulæ:

Pressures,

measured absolutely in pounds per square foot.

p_a = pressure of atmosphere.

p_1 = " in boiler and during admission in main cylinder.

p_2 = pressure of exhaust, = p_a when back pressure above atmosphere is not considered.

P_a, P_1, etc., the same measured in pounds per square inch, and above the atmosphere, except when otherwise stated.

TEMPERATURES,

in degrees Fahrenheit.

t_a = temperature of atmosphere.
t_b = " after compression in pump.
t_e = " upon leaving the fire.
t_1 = " of mixed air and steam.
t_2 = " of exhaust.
t_f = " at which feed water is supplied.

τ, τ_b etc., the same as measured from the absolute zero — 461.2° Fahr.

WEIGHTS,

in pounds per pound of air admitted.

w_e = weight of products of combustion.
w_s = " " steam formed.
w_1 = " " mixture of the two.

VOLUMES,

in cubic feet per pound of air admitted.

v_a = volume of one pound air when first admitted to compressing pump.
v_b = " " the same when compressed.
v_e = " " products of combustion at temperature of mixture.
v_s = " " steam at the same temperature.
v_1 = " " air and steam after mixture.
v_2 = " " mixture when expanded to atmospheric pressure.

RATIOS.

r = ratio of expansion in main cylinder.
r_c = " " compression in pump.
r_p = " " boiler to atmospheric pressure.
g_w = " " weight of steam to products of combustion.
g_v = " " volume " " " " " "
g_h = " " heat absorbed by steam to that remaining in air *above heat of compression.*

Those symbols relating to quantities of heat and work, efficiency, etc., are best given as they present themselves for discussion. The same is the case with the physical constants entering the calculations.

The quantities usually assumed as

DATA,

are P_a, P_1 and P_2, t_a, t_1 and t_2 from which p_a, p_1, p_2 and r_p, τ_a and τ_1 may be directly found; also H the total heat of combustion in foot-pounds, per pound of fuel, and N the number of pounds of air supplied for the same.

The points to be determined, are taken up in the order in which they naturally present themselves, beginning with the

HEAT OF COMPRESSION AND RATIO OF COMPRESSION IN PUMP.

Since the air is compressed without gain or loss of heat,

$$\frac{\tau_b}{\tau_a} = \left(\frac{p_1}{p_a}\right)^{\frac{\gamma-1}{\gamma}} = r_p^{\frac{\gamma-1}{\gamma}}$$

and

$$\frac{v_a}{v_b} = \left(\frac{p_1}{p_a}\right)^{\frac{1}{\gamma}} = r_p^{\frac{1}{\gamma}}$$

where $\gamma = 1.408$ for air. From these two equations it follows that

$$\tau_b = \tau_a r_p^{\frac{\gamma-1}{\gamma}} \qquad \text{and} \qquad r_e = r_p^{\frac{1}{\gamma}}$$

in which substituting the value of γ, and adapting to the use of logarithms, we get

$$\log. \tau_b = \log. \tau_a + 0{\cdot}29 \log. r_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\log. r_e = 0{\cdot}71 \log. r_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

from which t_b and r_e may be computed.

INITIAL TEMPERATURE T_e OF GASES LEAVING FIRE.

In finding this, t_h the temperature directly added by combustion, is first obtained by the formula

$$t_h = \frac{H}{772\,(1+N) \times 0{\cdot}238} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

the numbers 772 and 0·238, being Joule's equivalent and the specific heat of the products of combustion under constant pressure.

This temperature being added to that of the air leaving the pump, gives

$$t_e = t_b + t_h \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

RATIO OF HEAT OF COMBUSTION ABSORBED IN GASIFYING STEAM, TO THAT REMAINING IN AIR, ABOVE HEAT OF COMPRESSION.

On account of the transfer of heat in the boiler taking place at constant pressure, the quantities of heat are proportional to the changes in temperature, as is seen in the equation giving the desired ratio,

$$g_b = \frac{0{\cdot}238\ w_a\ (t_a - t_1)}{0{\cdot}238\ w_a\ (t_1 - t_b)} = \frac{t_a - t_1}{t_1 - t_b} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The percentages of heat entering steam and air, might, if necessary, be obtained from the formulæ

$$h_s = \frac{100 g_b}{1 + g_b} \text{ and } h_a = 100 - h_s.$$

WEIGHT OF PRODUCTS OF COMBUSTION PER POUND OF AIR ADMITTED.

$$w_a = \frac{1 + N}{N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

PROPORTIONS BY WEIGHT OF STEAM AND AIR.

Since the steam is to be in such quantity, that the heat required to form it in the gaseous state at $t_1°$ from the feed water, shall leave the air at the same temperature, and since the heat lost by the air is wholly taken up by the steam, we must have

$$0{\cdot}238\ w_a\ (t_a - t_1) = w_s \times h,$$

where h is equal to the total heat of gasification per pound of steam for any constant pressure, and has the empirically determined value of

$$1092 + 0{\cdot}475\ (t_1 - 32) - (t_f - 32)$$

thermal units. By substituting this in the previous equation and reducing, is obtained the following:

$$g_w = \frac{w_s}{w_a} = \frac{0{\cdot}238\ (t_a - t_1)}{1124 + 0{\cdot}475\ (t_1 - 32) - t_f} \quad \ldots\ldots\ldots\ldots (7)$$

$$\therefore \quad w_s = w_a \times g_w \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

and

$$w_1 = w_a + w_s = w_a\ (1 + g_w) \quad \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

PROPORTION BY VOLUME OF STEAM AND AIR.

For one pound of any gas we must have

$$\frac{p\ v}{\tau} = \frac{p_o\ v_o}{\tau_o} \text{ or } v = \frac{p_o\ v_o}{\tau_o} \times \frac{\tau}{p},$$

in which $\frac{p_o\ v_o}{\tau_o}$ is constant, and has for its value the difference between the dynamical specific heats under constant pressure and under constant volume, of the gas considered.

For air, $\frac{p_o\ v_o}{\tau_o}$ is equal to 53·15, and for steam 85·00 foot-pounds.

Since *the volume of the products of combustion is known to be almost exactly the same as that of the air supplied, for the same pressure and temperature*, in the present case v_s will be the volume of one pound of air at the pressure and temperature of superheating, or

$$v_s = 53{\cdot}15\,\frac{\tau_1}{p_1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

The volume of the steam will be that of a weight w_s, at the same pressure and temperature, or

$$v_s = 85\,\frac{\tau_1}{p_1} \times w_s \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

From v_s and v_a are directly obtained

$$q_v = \frac{v_s}{v_a} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

and

$$v_1 = v_a + v_s \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

Here, v_s, v_a and q_v, of course apply only to the volumes before mixture, as after mixture v_s and v_a each equal v_1 and $q_v = 1$. This diffusion of the air and steam to the same volume v_1, is accompanied by a corresponding fall in tension of each, but the sum of the two tensions remains equal to the pressure p_1 before mixture, and neither the resultant pressure, volume, or temperature is affected.

DETERMINATION OF THE VALUE OF γ, PROPER FOR MIXED AIR AND STEAM.

The general equation of adiabatic curves for any gas is

$$p = \text{constant} \times v^{-\gamma}$$

where γ is constant, and has for its value the ratio of the specific heat at constant pressure, to that at constant volume, of the gas under consideration.

Denoting by C_a^p and C_a^v, C_s^p and C_s^v, the specific heats at constant pressure and constant volume, of air and steam respectively, we thus have

for air

$$\gamma_a = \frac{C_a^p}{C_a^v} = \frac{0{\cdot}238}{0{\cdot}169} = 1{\cdot}408,$$

and for steam

$$\gamma_s = \frac{C_s}{C_s^v} = \frac{0{\cdot}480}{0{\cdot}370} = 1{\cdot}3$$

very nearly.

It should be mentioned that the specific heats of the products of combustion of all ordinary fuels, are stated by Rankine not to differ sensibly from those of pure air, and accordingly no distinction is here made.

To find γ_m, the value proper for air and steam mixed in the proportions already found, we may determine the two specific heats C_m^p and C_m^v of the mixture, and take their ratio.

As the weights w_s and w_w bear to each other the ratio q_w, and have w_1 for their sum,

$$C_m^p = \frac{(C_s^p + q_w\, C_s^p)\, w_c}{w_1} \qquad \text{and} \qquad C_m^v = \frac{(C_s^v + q_w\, C_s^v)\, w_c}{w_1}$$

$$\therefore \gamma_m = \frac{C_m^p}{C_m^v} = \frac{(C_s^p + q_w\, C_s^p)\, w_c}{w_1} \times \frac{w_1}{(C_s^v + q_w\, C_s^v)\, w_c} = \frac{C_s^p + q_w\, C_s^p}{C_s^v + q_w\, C_s^v},$$

in which substituting the values of the several specific heats,

$$\gamma_m = \frac{0{\cdot}238 + 0{\cdot}48\, q_w}{0{\cdot}169 + 0{\cdot}37\, q_w} \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

To use γ_m as thus calculated, it is necessary that the mixture be sufficiently superheated above the point of saturation of the steam, to keep the latter in the truly gaseous state, a condition that would probably be realized in most actual examples.

RATIO OF EXPANSION IN MAIN CYLINDER, AND TEMPERATURE OF EXHAUST.

It is here assumed, owing to the insulating action of the air in mixture, and to the cylinders being properly clothed to prevent conduction and radiation, that no appreciable quantity of heat is lost, and consequently that the curve of expansion will be truly adiabatic, in which case, analogous to that of the compressing pump,

$$\tau_2 = \tau_1 \left(\frac{p_2}{p_1}\right)^{\frac{\gamma_m - 1}{\gamma_m}} \qquad \text{and} \qquad r = \left(\frac{p_1}{p_2}\right)^{\frac{1}{\gamma_m}}$$

or taking the atmospheric pressure for p_2, since $\frac{p_2}{p_1}$ reduces to $\frac{p_s}{p_1} = r_p{}^{-1}$

$$\tau_2 = \tau_1\, r_p{}^{\frac{-\gamma_m - 1}{\gamma_m}} \qquad \text{and} \qquad r = r^{\frac{1}{\gamma_m}}$$

from which follow,

$$\log.\ \tau_2 = \log.\ \tau_1 + \frac{\gamma_m - 1}{\gamma_m}\,[\text{a. c. log. } r_p] \ldots\ldots\ldots [15]$$

and

$$\log.\ r = \frac{1}{\gamma_m} \log.\ r_p \ldots\ldots\ldots\ldots\ldots\ldots [16]$$

VOLUMES OF MAIN AND PUMP CYLINDERS, PER POUND OF AIR ADMITTED.

Main cylinder, $v_2 = r\, v_1 \ldots\ldots\ldots\ldots [17]$

Pump cylinder, $v_s = 53{\cdot}15 \frac{\tau_s}{p_s} \ldots\ldots\ldots\ldots [18]$

RATIO IN WHICH THE SPACE SWEPT BY THE PUMP PISTON, IS LESS THAN THAT SWEPT BY MAIN PISTON,

$$q_c = \frac{v_s}{v_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [19]$$

MEAN FORWARD ABSOLUTE PRESSURES ON MAIN AND PUMP PISTONS.

In the main cylinder where the curve of expansion has for its equation

$$p = \text{constant} \times v^{-\gamma_m}$$

it may be demonstrated by the integral calculus, according to the general method set forth in Rankine, that q_m the ratio of the mean forward pressure p_m to the initial pressure p_1, is given by the formula.

$$q_m = \frac{p_m}{p^1} = \frac{\gamma_m r^{-1} - r^{-\gamma_m}}{\gamma_m - 1} = \frac{\frac{\gamma_m}{r} - \frac{1}{r_p}}{\gamma_m - 1} \quad \ldots\ldots[20]$$

from which $$p_m = q_m p \quad \ldots\ldots[21]$$

For the pump, denoting the ratio by q_a, and the mean pressure by p_a, we have in a similar manner,

$$q_a = \frac{p_a}{p_1} = \frac{\frac{\gamma_a}{r_c} - \frac{1}{r_p}}{\gamma_a - 1} \quad \ldots\ldots[22]$$

and $$p_a = q_a p_1 \quad \ldots\ldots[23]$$

GROSS WORK IN MAIN CYLINDER.

$$U_m = (p_m - p_a) \times v_2 \quad \ldots\ldots[24]$$

WORK OF RESISTANCE OF PUMP

$$U_a = (p_a - p_a) \times v_a \quad \ldots\ldots[25]$$

EFFECTIVE WORK DEVELOPED, PER POUND OF AIR ADMITTED.

$$U_e = U_m - U_a \quad \ldots\ldots[26]$$

HEAT OF COMBUSTION USED FOR THE SAME, IN FOOT-POUNDS.

$$H_1 = \frac{H}{N} \quad \ldots\ldots[27]$$

HEAT REJECTED IN EXHAUST, IN FOOT POUNDS.

$$H_2 = H^1 - U_e \quad \ldots\ldots[28]$$

MEAN EFFECTIVE PRESSURE, OR PRESSURE IN MAIN CYLINDER, EQUIVALENT TO PERFORMANCE OF WORK.

$$P_e = \frac{U_e}{V_2} \quad \ldots\ldots[29]$$

When given in pounds per square foot, as directly computed from this formula, P_e further represents the effective energy developed per cubic foot swept through by the main piston.

PRESSURE EQUIVALENT TO EXPENDITURE OF HEAT.

$$P_h = \frac{H_1}{V_2} \quad \text{.....[30]}$$

EFFICIENCY OF FLUID.

$$E = \frac{U_e}{H_1} = \frac{P_e}{P_h} \quad \text{.....[31]}$$

This also includes the *efficiency of the furnace,* which for the given form of boiler is unity, because of there being no waste heat up the chimney.

WEIGHT OF FUEL USED, PER EFFECTIVE HORSE POWER PER HOUR.

Since the work performed per pound ot fuel is $N \times U_e$, and there are 1,980,000 foot pounds to be performed by the desired weight C of that fuel, it follows that

$$C = \frac{1{,}980{,}000.}{N \times U_e} = \frac{1{,}980{,}000.}{E \times H.} \quad \text{.....[32]}$$

The following formulæ were not applied in a majority of the examples, and their deduction is in consequence placed last. They relate to the

DETERMINATION OF THE PRESSURE OR TENSION OF THE STEAM IN THE MIXTURE, AND THE TEMPERATURE TO WHICH IT WOULD HAVE TO BE LOWERED, FOR CONDENSATION TO OCCUR AT THE EXHAUST PRESSURE.

There is first to be found q_d, the ratio of p_s the tension of the steam to p_a that of the air, when thorough mixture has taken place. As long as the steam remains gaseous we have

$$\frac{p_s v_s}{\tau_s} = 85\ w_s \qquad \text{and} \qquad \frac{p_a v_a}{\tau_a} = 53.15\ w_a$$

Dividing the first of these equations by the second, and noting that $\tau_s = \tau_a =$ the temperature at any point of the expansion of the mixture, we have further

$$\frac{p_s v_s}{p\ v_a} = \frac{85\ w_s}{53.15\ w_a}, \text{ or } \frac{p_s}{p_a} = \frac{v_a}{v_s} \times \frac{w_a}{w_s} \times \frac{85}{53.15}$$

$$\therefore q_d = \frac{p_s}{p} = \frac{q_w}{q_v} \times \frac{85}{53.15} \quad \text{.....[33]}$$

To find p for any particular value of p the whole pressure of the

mixture, since

$$p = p_a + p_s \qquad \text{and} \qquad p'_s = q_s \times p_s$$

$$p_s = q_s\, p - q_s\, p_s \qquad \text{or} \qquad p_s\,(1+q_s) = q_s\, p.$$

$$\therefore \quad p_s = \frac{q_s}{1+q_s} \times p \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [34]$$

By substituting p_2 for p, in this equation, and calculating the value of p_s, the desired temperature t_4 of condensation at the exhaust pressure may be directly found, as being the boiling point corresponding to this fractional pressure.

For the approximate purposes to which this last set of formulæ is here applied, the errors arising from the departure of steam from truly gaseous laws, while closely approaching saturation, may be neglected.

A comparison of t_4 with t_2, the exhaust temperature already found on the assumption that all of the steam remained gaseous throughout expansion, will show whether any condensation has occurred, or not, and if so it will enable a judgment to be made as to how far the calculations of work based upon gaseous expansion, are affected.

Owing to the fact of the air tending to cool more rapidly than the steam, while expanding without gain or loss of heat, the latter constantly approaches saturation, and will finally begin to condense if the mixture has not been in the first place sufficiently super-heated for the given ratio of expansion. Formulæ could be deduced to locate on the diagram the exact point at which condensation would first occur, and to calculate the work as measured by the area of the diagram with theoretic precision, but their complexity would not warrant their use, and it will be subsequently seen that in those of the examples following, where the effects of this condensation enter at all, the results of calculations on work and efficiency, though not influenced to any practical degree, will be if anything less than their true values.

The numerical examples, six in number, are now given in tabular form and in the order in which they were originally worked out, as being applicable to the plan of aero-steam engine considered, while working under several conditions, relative to the higher limiting pressures and temperatures, and with varying supplies of air, above the amount necessary for complete combustion. These quantities were chosen to fall within the limits of possible practice, and at the same time to give those results most likely to be applied with advantage to this form of engine.

In the first example given, the temperature t_2 of exhaust was chosen at 212° Fahr. to make a more direct comparison with the common high-

pressure steam engine, and the boiler pressure p_1 afterwards calculated, but in the other five, it was found best to place p_1 among the data instead of t_2, the order of all the determinations remaining as in the general formulæ.

The following data are common to all of the examples, and therefore are here introduced, to be referred to when needed.

COMMON DATA.

$P_a = P_2 = 14{\cdot}7$ lbs. per square inch, or $p_a = p_2 = 2116{\cdot}4$ lbs. per square foot.

$H = 10{,}000{,}000$ foot pounds or somewhat less than 13,000 British thermal units, a fair value for good coal whether bituminous or anthracite.

$t_a = 50°$, being roughly assumed as about the average atmospheric temperature in this climate.

$t_f = 100°$ a value that is supposed to be reached by the use of a feed-water heater attached to the exhaust of the engine.

The least quantity of air practically required for the complete combustion of one pound of average coal or coke, was taken at 18 pounds, being about 1·5 times the amount theoretically necessary to furnish the oxygen for combination.

Upon the succeeding page is given the table of examples, arranged as far as possible with reference to compactness. The horizontal row of figures on the top of the table refers to the examples, and the vertical one on the left, to the general formulæ as is there indicated.

The numerical calculations are only carried out so far as to prevent any practically considerable errors from arising. For ratios having values near unity, three places of decimals is considered to be amply sufficient.

The value of g_h, in the third and fifth examples, is caused to come out negative by the fact of t_b exceeding t_1 in which case it should be defined as the ratio of the combined quantities of heat supplied to the steam, both from the fire and the excess of heat of compression, to this latter excess, lost from the air by its fall in temperature from $t_b°$ to $t_1°$

Table of Numerical Calculations on Aero-Steam Engines.

	No. of formula.	Symbol for quantity.	Denomination of quantity.	No. of Example. 1	2	3	4	5	6
Data.	....	P_1	above atmos. lbs. sq. in.	32·63	60·	100·	100·	100·	60·
	....	t_1	deg. Fahr.	450·	450·	450·	600·	450·	600·
	....	N	lbs.	18·	18·	18·	18·	54·	54·
Results per pound of air admitted.	1	t_b	deg.	256·1	357·9	466·4	466·4	466·4	357·9
	2	r_c	ratio.	2·294	3·172	4·301	4·301	4·301	3·172
	3	t_a	deg.	2864·5	2864·5	2864·5	2864·5	989·6	989·6
	4	t_c	"	3120·6	3222·4	3330·9	3330·9	1456·0	1347·5
	5	q_b	ratio.	13·773	30·102	—175.7	20·440	—61·34	3·088
	6	w_c	lbs.	1·056	1·056	1 056	1·056	1·019	1·019
	7	q_w	ratio.	0·519	0·540	0·561	0·502	0·196	0·137
	8	w_s	lbs.	0·547	0·570	0·592	0·530	0·200	0·140
	9	w_1	"	1·603	1·626	1·648	1·586	1·219	1·159
	10	v_c	cu. ft.	7·106	4·503	2·932	3·418	2·932	5·246
	11	v_s	"	6·218	4·104	2·759	2·897	0·957	1·174
	12	q_v	ratio.	0·875	0·911	0·941	0·848	0·326	0·223
	13	v_1	cu. ft.	13·324	8·607	5·691	6·315	3·889	6·420
	14	γ_m	ratio.	1·349	1·348	1·347	1·349	1·375	1·383
	15	t_2	de .	212·0	137·9	75·1	162·1	58·8	215·2
	16	r	ratio.	2·380	3·336	4·593	4·584	4·454	3·239
	17	v_2	cu. ft.	31·71	28·71	26·14	28·95	17·32	20·80
	18	v_a	"	12·84	12·84	12·84	12·84	12·84	12·84
	19	q_c	ratio.	0·405	0·447	0·491	0·444	0·741	0·612
	20	g_m	"	0·734	0·596	0·476	0·476	0·482	0·601
	21	p_m	lbs. sq. ft.	5004·9	6410·8	1861·8	7861·8	7960·9	6464·6
	22	q_n	ratio.	0·732	0·606	0·488	0·488	0·488	0·606
	23	p_n	lbs. sq. ft.	4989·3	6518.3	8060·0	8060·0	8060·0	6518·3
	24	U_m	ft. lbs.	91597·	123296·	150179·	166306·	101227·	90429·
	25	U_n	"	36888·	56516·	76310·	76310·	76310·	56516·
	26	U_e	"	54709·	66780·	73869·	89996·	24917·	33913·
	27	H_1	"	555555·	555555·	555555·	555555·	185185·	185185·
	28	H_2	"	500846·	488775·	481686·	465559·	160268.	151272·
	29	P_e	absol. pres. lbs. sq. ft.	1729·2	2326·0	2825·9	3109·1	1438·6	1630·6
	"	"	" " in.	11·98	16·15	19·63	21·59	9·99	11·33
	30	P_h	" " ft.	17520·	19350·	21253.	19192·8	10692·0	8904·4
	31	E	ratio.	0·098	0·120	0·133	0·162	0·135	0·183
	32	C	lbs.	2·011	1·647	1·489	1·222	1·471	1·082

[Entered according to act of Congress, in the year 1873, by John Richards, in the office of the Librarian of Congress at Washington.]

THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. RICHARDS, Mechanical Engineer.

[Continued from vol. lxviii., page 34.]

Fifth.—Shrinkage, the allowance that has to be made for the contraction of the castings in cooling, in other words, the difference between the size of the pattern and the size of the casting. This is a simple matter apparently, that may be provided for in allowing a certain amount of shrinkage in all directions, but when the inequalities of shrinkage both as to time and degree are taken into account it becomes a problem of no little complication.

Sixth.—Inherent or cooling strains, that may either spring and warp the castings, or weaken them by maintained tension in certain parts, a condition that often requires a disposition of the metal quite different from what the working strains demand.

Seventh.—Draught, the bevel or inclination on the sides of patterns to allow them to be withdrawn from the moulds without dragging or breaking the sand.

Eighth.—Rapping plates, draw plates, and lifting irons for lifting out the patterns. Fallow and match boards, with other details that are peculiar to patterns, and have no counterparts neither in names nor uses outside the foundry.

This makes a statement in brief of what constitutes a knowledge of pattern making, and what must be understood not only by pattern makers but also by any mechanical engineer who undertakes to design machinery, or manage its construction successfully.

As to the manner of cutting out, or planing up the lumber for patterns, and the manner of framing it together, it is useless to devote space to the matter here; one hour's practical observation in a pattern shop and another hour spent in examining different patterns, is worth more to the apprentice than a whole volume written to explain how these last-named operations are performed. A pattern, unless finished with paint or opaque varnish, will show the manner in which the wood is disposed in its construction. The operation of power tools for wood cutting so far as they can be applied in pattern making is easily understood from general principles.

I will therefore proceed to review these conditions or principles in pattern making and casting in a more detailed way furnishing as far as possible the reasons for different modes of constructing patterns, and the various plans of moulding and casting.

In regard to the character or quality of wood patterns, as already stated, they can be made at greater or less expense, and, if necessary, capable of almost any degree of endurance. The writer has recently had occasion to examine patterns that have been used more than two hundred times and are apparently good for an equal amount of use. Such patterns are expensive at the beginning, but the cheapest in the end, if they are used for a large number of castings. For a special piece, or to be used for a few times, to make such a pattern would be unnecessary and a useless expense, yet with patterns, as with everything else pertaining to machinery, the safest plan is to err on the strong side.

For pullies, gear wheels, or other standard parts that are not likely to be modified or changed, iron patterns are best; wood patterns, for gear wheels and pullies, aside from their liability to spring and warp cannot from the nature of the pieces be made sufficiently strong to withstand foundry use; besides, the greatest accuracy that can be attained by metal patterns is far from producing true castings, especially for tooth wheels. The more perfect the patterns are the less rapping its required to draw them, and the less the rapping the more perfect the castings will be.

The most perfect castings for both gear wheels and pullies are made by drawing the patterns through templates without rapping. These templates are simply plates of metal perforated so that the pattern can be forced through them by screws or levers, leaving the sand intact. Such templates are expensive to begin with, because of the accurate fitting that is required, especially around the teeth of wheels, and the mechanism that is required in drawing the patterns, but when a large number of pieces is to be made from one pattern such as gear wheels or pulleys, the saving of labor is quite enough to pay for the outfit, to say nothing of the saving of metal which often amounts to ten per-cent, and the increased value of the castings which generally exceeds ten per-cent, because of their accuracy.

Mr. Ransome of Ipswich, England, where this template moulding originated, has invented a process of fitting the templates for gear wheels and other irregular forms by pouring melted white metal around the teeth of wheels, which effects a great saving in cost, and answers quite as well as to cut the pattern through to an exact fit in the iron platen.

The plans of moulding a piece in the foundry, or the manner in which patterns are constructed with reference to moulding, is governed by the same conditions that determine the durability and strength of patterns.

The cost of forming a pattern mould is divided between the foundry and the pattern shop. What the pattern maker saves the moulder may lose, and what the pattern maker spends the moulder may save; in other words there is a point beyond which saving in patterns is ballanced by the extra labor and waste in casting, a fact that is not generally realized because of the inaccurate records kept of pattern work and the imperfect records that are generally kept of foundry work. A moulder may cut all the fillets in a mould with a trowel, he may stop off, fill up, and print in to save pattern work, but it is only expedient to do so when it costs very much less than to prepare proper patterns, because much patching and cutting in a mould seldom improves it.

The reader will notice as we go along how everything pertaining to patterns and moulding resolves itself into a matter of judgment in each case, and how difficult it would be to apply general rules.

The arrangement of patterns with reference to having certain parts of castings solid and clean is an important matter, yet one that is comparatively easy to understand. The top of the mould or the cope as it is called, contains the dirt, while the bottom or drag side is generally clean and sound, and the rule is to arrange patterns so that the surfaces to be finished will come on the bottom or drag side.

Supposing the iron in the mould to be in a melted state and to contain as it always must, loose sand and 'scruff,' and that the weight of the dirt is to the melted iron as the weight of cork is to water, it is easy to see where this dirt would lodge and where it would be found in the castings.

Expedients to avoid dirt in castings that are to be finished all over or on two sides are various. Careful moulding to avoid loose sand and washing are the first requisite; sinking heads that rise above the moulds are commonly employed when the castings is of a form that allows the dirt to collect at one point. The moulds for sinking heads are formed by the moulder as a rule, and have nothing to do with the patterns.

The quality of castings are affected by a great many things besides what has been already named, such as the manner of gating or flowing the metal into the moulds, the temperature and quality of the iron, the temperature and character of the mould; things which any skilled

foundryman will take pleasure in explaining, in answer to courteous and proper questions.

All these various things pertaining to castings must be understood by the pattern maker, that is, he must know how far his provisions are to meet them, and how far the moulder is to be responsible for the quality of the work produced.

Cores are mainly used for what we may term the displacement of metal in the moulds. There is no clear line of distinction between cores and moulds, as founding is now conducted. Cores may be of green sand and made to surround the exterior of a piece, as well as to make perforations or to form recesses within it. The term "core" in its technical sense means dried moulds, as distinguished from green sand. Wheels for instance, are said to be cast in cores when the mould is made in pieces, and dried. Supporting and venting cores, and their expansion are some of the obscure conditions to which we call the apprentice's attention. When a core is surrounded with hot metal, it gives off from its moisture, and the burning of the 'wash,' a large amount of gas which must have free means of escape. In the arrangement of cores, therefore, attention must be had to some plan of venting, by allowing them to project out through the sides of the mould and communicate with the air.

The apprentice can get a clear idea of this venting process, by examining a tubular core barrel, such as is used in moulding pipes or hollow columns, or by examining large cores about a foundry. Provision of some kind to "carry off the vent," as it is termed, by moulders, will be found in every case.

The venting of moulds is even more important than venting cores because core vents only carry off the gases generated within the core itself, while the gas from its exterior surface, and from the whole mould, has to find means of escaping rapidly when the hot metal enters the mould.

The apprentice will, no doubt, wonder why sand is used for moulding, instead of some more adhesive material like clay. If he is not too fastidious for the experiment, and will apply a lump of damp moulding sand to his mouth and blow his breath through the sand, the query will be solved. If it were not for the porous nature of sand-moulds they would be blown to pieces as soon as the hot metal entered them; not only from the mechanical expansion of the gas, but from its explosion by combustion; the gas jets from moulds, as may be seen at any time in pouring hot metal, will take fire and burn as they issue from the moulds.

If it were not for venting moulds they could be made from plastic material so as to produce finer castings with clear sharp outlines.

The means of supporting cores must be devised, or at least understood by pattern makers, and consist of "prints" and "anchors;" prints are extensions of the cores that project through the casting and extend into the sides of the moulds to be held by the sand and sometimes by the flask; the prints of cores have duplicates on the patterns, which are, or should be, of a different color from the patterns, so as to distinguish them from other parts.

The amount of surface required to support cores is dependent upon their weight, or rather upon their cubic contents, because the weight of a core is but a trifling matter compared to its floating force when surrounded by melted metal. The apprentice in studying the problem of supporting cores must remember that the main force needed is to hold them down, and not to bear their weights. The floating force of a core is as the difference between its weight and that of a solid of metal of the same size, a matter that moulders often forget to consider. It is often impossible, from the nature of castings, to have prints large enough to support the cores, and it is then effected by anchors, pieces of iron that stand like braces between the cores and the flasks, or pieces of iron imbedded in the sand to receive the thrust or strain of the anchors.

A safe rule about cores in constructing patterns, is that whenever a question arises between cored and rib sections, or cored and box patterns is to employ cores. The usual estimate of the difference between the cost of moulding rib and cored sections, as well as of skeleton and cored patterns is wrong. The expense of cores is often balanced by the advantage of having an 'open mould' that is accessible for repairs or facing, and by the greater durability and convenience of the solid patterns.

Taking a column or box frame for machinery that might be made either with a rib or a cored section, as an example, it would seem at first thought that the patterns for a cored column would cost much more by reason of the core boxes, but it must be remembered that in most patterns labor is the principal item of cost, and what is lost in the extra lumber required for a core box or in making a solid pattern, is in many cases more than represented in the difference of labor in favor of the solid pattern.

Cores expand when heated and require an allowance in their dimensions the reverse from patterns; this is especially the case when the cores are made upon iron frames. For cylindrical cores less than six

inches diameter, or less than two feet long, the expansion need not be taken into account by the pattern maker, but for large cores it requires careful calculation. The expansion of cores is as the degree of heat they reach, and this is contingent upon the amount of metal that may surround the core and its conducting power.

Shrinkage, or the contraction of castings in cooling is provided for by adding from one tenth to one eighth of an inch to the foot in making patterns; this is a simple matter and is accomplished without trouble by laying down the pattern drawings from the figured dimensions of the finished work, employing a shrink rule that is about one hundredth part longer than the standard scale.

This matter of shrinkage is indeed the only condition in pattern making that is governed by anything like constant rules, and even this sometimes requires to be varied to meet special cases. For small patterns whose dimensions do not exceed one foot in any direction, the rapping will generally make up for shrinkage and no allowance is required in the patterns, but pattern makers are so partial to the rule of shrinkage, as the only constant one in their business, that they are averse to admitting exceptions, and usually keep to the shrink rule for all pieces, whether large or small.

Inherent or cooling strains in castings is much more intricate than shrinkage; it is in fact one of the most uncertain and obscure matters that pattern makers and moulders have to contend with. Inherent strains that may weaken castings or cause them to break while cooling, or sometimes even after they are finished, must in many kinds of work be carefully considered, both in the preparation of designs and the arrangement of patterns, especially for wheels and pullies that have spokes, and in struts or braces that have both ends fixed.

The main consideration connected with cooling strains however, is that of the castings being warped and sprung; this difficulty is continually present in the foundry and machine shop, and there is perhaps no question in the whole range of mechanical manipulation about which people will differ more than as to the means to prevent the springing of castings. This being the case the apprentice can hardly hope for much information here, yet there is no doubt but what the springing and strains in casting are the result of constant causes and principles that might be fully understood if it were not for the ever changing conditions that exist in casting both as to the form of the piece and the temperature and quality of the metal that is used.

Springing and warping of castings is the result of unequal strains,

caused by one part cooling or "setting" sooner than another. Thus far all seems clear, but the next step takes us into the dark. What produces irregular cooling and how is it to be avoided? These are the questions that must be dealt with to secure true castings.

Irregularity of cooling may be the result of unequal conducting power in different parts of the mould or cores, or it may be from the varying dimensions of the castings which contain heat as the thickness, and give it off in the same ratio.

As a rule, the drag or bottom side of a casting cools first, especially if the mould rests on the earth and there is not much sand between the castings and the earth. This is a common cause of unequal cooling, especially in large flat pieces. The air being a bad conductor of heat and the sand usually thin on the cope side and the sides protected by the flask, the result is that the top of moulds becomes quite hot, while at the bottom the earth being a good conductor, carries off the heat and cools that side first, so that the iron 'sets' first on the bottom and then cools and shortens on the top, causing convexity on the underside.

This is but one out of many influences that tend to irregular cooling and is described with a view of giving the apprentice a clue from which to search for others.

The want of uniformity in sections which produces irregular cooling can be avoided by a disposition of the metal to meet it. This, so far as the extra metal that has to be used to balance castings is a waste that engineers are loath to consent to, and seldom recognize in their designs for moulded parts; yet the difficulty of irregular cooling can be in a large degree met by a proper distribution of the metal without wasting it to balance strains, if the matter is understood by the engineer. No one is prepared to make designs for castings who has not studied the subject of cooling strains as thoroughly as possible by practical examples as well as from theoretical deductions.

The quality of the metal, the temperature at which it is poured and the manner of gateing, all have to do with the truth of castings, but the space here will not allow the subject of moulding to be noticed farther.

Draught, or the taper required to allow patterns to be drawn readily is another of those indefinite conditions in pattern making that must be constantly a question of judgment and experience. It is not uncommon to find rules for the draught of patterns laid down in books, but it would be difficult to find any such rules applied. The draught

may be one sixteenth of an inch to each foot of depth, or it may be one inch to a foot of depth or there may be no draught whatever. Any rule considered aside from specified conditions would only confuse a learner. The only plan to understand the proper amount of draught for patterns is to study the matter in connection with the patterns and the foundry.

Patterns that are deep and for castings that require to be parallel or square when finished, are made with the least possible amount of draught. If a pattern is a plain form that affords facilities for lifting or drawing, it may be drawn without taper, if its sides are smooth and well finished. Pieces that are shallow and moulded often should, as a matter of convenience, have as much taper as possible, and as the quantity of taper can be as the depth of a pattern, we frequently see them made with a taper that exceeds one inch to the foot of depth.

Moulders generally rap patterns as much as they will stand, often more than they will stand, and in providing for draft it is necessary to take these customs into account; there is no use in making provision to save rapping unless the rapping is omitted.

Rapping plates, draw irons and other details of pattern making are soon understood by observations. Perhaps the most useful suggestion I can offer is to say that draw irons should be set on the under side, or the bottom of patterns instead of on the top where they are generally placed. A draw plate set in this way with a hole bored through the pattern so as to insert the draw-irons from the top, cannot pull off, which it is sure to do if set on the top side.

Every pattern should be ironed with dowel pins, draw and rapping plates, no matter how small the pattern is, unless it is some trifling piece. If a system of draw irons is not rigidly carried out, moulders will not trouble themselves to take care of patterns.

In conclusion I will say on the subject of patterns and castings that the learner must depend mainly upon what he can see and what is explained to him in the pattern shop and foundry. He need never fear an uncivil answer to a proper question applied at the right time and place; mechanics who have enough knowledge to impart useful information about their business have invariably the courtesy and good sense to impart such information to those who require it.

The apprentice should never ask questions about simple and obvious matters, or about such things as he can easily learn by his own efforts. The more difficult a question is, the more pleasure a skilled man will take in answering it; in short, let the apprentice consider his ques-

tions before asking them; a good plan is to write them down, and when he wants information about casting, never go to the foundry to interrupt a manager or moulder at melting time, nor in the morning when no one wants to be annoyed with questions.

I will, in connection with this subject of patterns and castings, suggest a plan of learning that is especially applicable in this case—that of adapting the habit of imagining the manner of moulding, and the kind of pattern used in producing each casting that comes under notice.

Such a habit soon becomes easy and natural in a short time, and is a sure means of acquiring an extended knowledge of patterns and moulding.

A pattern maker no sooner sees a casting than he imagines the kind of pattern used in moulding it. A moulder would imagine the plan of moulding and casting it, while an engineer will criticise the proportions and think of the strains upon which they are based, and how much skill was brought to bear in making the original designs. The engineer will also imagine the moulding and castings of a casting so far as affected by its designs and if skilled as he ought to be, will detect at a glance any useless cost of patterns or expense in moulding.

To be continued.

Birmingham Steel Pens.—The number of steel pens made in Birmingham per week is 9,800 gross, or 14,112,000 pens. Twenty years ago, Birmingham pens sold at 5 shillings (1¼ dollars) the gross; to-day the best pens are sold at three cents the gross. If we consider that in a gross there are 144 separate pieces of steel and that each of these pieces passes through twelve hands before becoming a perfect pen, the fact that these 144 pens are furnished for three cents after having paid for the material, paid the wages of the workmen and yielded a paying profit, is one of the most convincing demonstrations of the value of the results obtained by the employment of machinery and the division of labor.

Chemistry, Physics, Technology, etc.

THE EXTERNAL ASPECTS OF THE SUN—ITS PHOTOSPHERE AND SPOTS—ITS CHROMOSPHERE AND CORONA.

By Professor S. P. Langley.*

If any one were called on for a description of the earth on which we live, with all its lands and waters, it would be well understood that the task was a heavy one, and that even an abstract of such a theme might occupy days of discourse. But the subject of the Sun is, if anything, still more extensive, and you will, I am sure, understand that in taking it as a topic of a single lecture, I have no pretension to do more than to epitomize a part of our knowledge.

The tendency to divide research has been felt here as elsewhere. Even in astronomy we have specialties within specialties, and among observers, giving much attention to the Sun, some who devote their time to studying the laws of the motion of the spots, some to those of the emission of its light and heat, some to investigations with the aid of spectrum analysis, and many more subdivisions of labor beside; and since, if we attempt an allusion to all these topics, an hour would give time only to read, as it were, the headings of the chapters of our knowledge, I prefer to take one of these chapters by itself, and to speak to-night chiefly of the external aspects of the Sun, of the sources of our knowledge of it, and of the things which come in such connection.

To do this, since I cannot take you to an observatory, I have brought here one or two of the instruments by which such research is actually carried on. I cannot bring the Sun, but I can bring some pictures of it, certainly authentic, since the Sun himself made them, and I will try to project them on this screen, so that all may see. Before doing so however, let us look a moment at this little representation of the Sun, as if at a sort of outline map of an unknown region we are going to explore.

[The Lecturer pointed to a representation of the Sun and Corona, suspended near the front of the stage.]

THE PHOTOSPHERE.

This circle represents the Photosphere of the Sun, the photosphere

*[A Lecture delivered in Pittsburgh, April 21st, 1874.]

being simply what its name implies, the sphere of light, or in other words, the Sun's visible surface and what we see daily with the naked eye. Outside this is a thin envelope, rising here and there into irregular prominences. This is the Chromosphere, the color sphere, a thin shell of crimson and scarlet tint, invisible even to the telescope, except at the time of a total eclipse, when alone its true color is discernible, but seen exactly as to its form, at all times by the spectroscope. Outside of all this is this strange shape which represents the still mysterious "Corona," invisible as yet to the spectroscope. There are other subdivisions of which I do not speak, but let us carry in our minds the three main divisions, the Photosphere—or visible surface of the Sun, within which lies nearly all its mass—the Chromosphere, and the Corona; the latter being very faint and unsubstantial, but as to size enormous and larger than all the rest.

Almost everything in practical astronomy resolves itself into a measurement of some sort and a subsequent computation, for it is a science which especially deals with the greater works of that Power which made all things by number, weight and measure.

Measurements of precision therefore are at the foundation of all sound astronomical knowledge, and these in the case of the Sun, are largely carried on by the Position Filar Micrometer, the little instrument before me. [Instrument exhibited.]

It consists here essentially of a screw whose threads are so fine that there are one hundred of them in an inch. One complete turn of the screw then advances its point 1-100 of an inch. It has a very large circular head, whose circumference is itself divided into sixty parts, so that we can reckon one sixtieth part of a turn, or a motion of 1-6,000 part of an inch. We can in fact do much more, the 1-60,000 part of an inch being customarily reckoned in practice. Now to observe these small motions, we use high magnifying powers, and to obtain a pointer delicate enough, we take commonly threads from the coccoon of the little spider which builds in decayed wood and which are far finer than those of a cobweb. Since they would be invisible to you, I have replaced them for this occasion, by fibres of raw silk; but I will continue to speak of them as the "web." The "web" then is attached to sliding frames moved by the screw, so that the heads can be made to approach or recede from each other.

THE MICROMETER.

[The micrometer was now placed so that its eye piece projected the

image of the "web," illuminated by the lime light, upon a large screen near the back of the stage.]

You see them now upon the screen, (Fig. 1.) where they look as large as ropes. To give an idea of their real size, I put a cambric needle beside them.

[This magnified image of the head of the needle was thrown on the screen with the web.*]

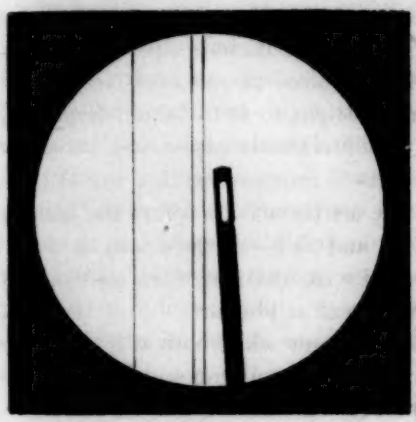


Fig. 1.

You see that the middle thread looks larger than the others. This is because two threads are there placed nearly in line. To show how they pass each other, and how they are controlled, I now move one of them through the space of 1-200th of an inch. Those who are nearest see that they have separated, and that the light appears between them. I move them through 1-50th of an inch and the change is, I hope, now visible to the most distant spectator. Such is one part of the means of celestial measurement, for though we cannot apply these threads directly to the Sun, we can place the micrometer in the telescope just where the image of the Sun is formed and measure that.

But here a new difficulty arises. The large lens at the end of the telescope, which forms the image, necessarily acts as a burning glass, and concentrates both light and heat there in an intolerable degree. That of the equatorial at Allegheny is 13 inches in diameter, and when its heat is concentrated by the proper lenses, it is intense enough to melt iron, and its light is increased in proportion. Now the eye must somehow rest on the image of the Sun in spite of the intolerable brilliance and heat, and the old observers used to look when the luminary was hidden by clouds, though afterwards colored glasses were used. Sir William Herschel used glass cells filled with diluted ink, to shield the eye, but these and other such contrivances have been lately discarded in favor of an apparatus which does not interpose any dark or colored screen, and yet cuts off all the light and heat we wish to dispense with.

*We are indebted for the wood-cuts which illustrate this lecture, to the courtesy of the Pittsburgh *Evening Telegraph*.—Ed.

THE POLARIZING EYE-PIECE.

This is the Polarizing Eye-piece, an instrument which has lately been independently invented by several observers as their needs called for it. The instrument before you is the embodiment of an idea which occurred to me long since, and which, some four years ago, the liberality of a citizen of Pittsburgh to the Allegheny observatory, enabled me to have executed for its use. It is constructed especially for the telescope, and is not adapted for lecture experiment; but here is another example of the same principle, which will enable me to illustrate its action. In each of these two little tubes there is a perfectly transparent substance, as you see, when I place them successively before the lantern, by their transmitting its light so as to form a bright circle on the screen. According to all common experience, we might suppose that since either taken singly is transparent, they would be so taken together, and that when I place them both before the lantern, its light would pass through both, and fall on the screen as before. But you see that this is not necessarily so, and that when united, they become as it were, opaque or transparent at pleasure. Now the beam is evidently passing through both, and now while both still remain in a position to let it pass, as I turn one of them, you see the light fade and disappear. It is just as though on turning one of the sashes in a double window upside down, we found that we could not see through the window at all, the panes becoming opaque as a mill-stone in the reversed position, and transmitting more and more light as we turned them upright again. As I turn this over, you see the light waning just as though the brilliant flame behind it were dying out; now you can scarcely see the outline of the circle on the screen, now it is gone, and at a touch it shines out again. This is due to the polarization of the light, and with the Polarizing Eye-piece which I now hold up before you, and which is constructed on a similar principle, I have studied the Sun for years, at times keeping my eye gazing for four or five consecutive hours at the details of its surface without injury or fatigue.*

PHOTOGRAPHY.

This is one means of the study of the Sun, but another and most important one is photography. Great difficulties have been found in photographing the Sun; one, of course, being the intensity of light, and in this case the evil has been avoided by an extremely brief ex-

*For a description of this Instrument, see this Journal, Vol. xci. No. 541, p. 115.

posure. All of us know what a tedious minute we pass while sitting for our photograph. The Sun's portrait is more quickly taken, a special arrangement reducing the time in his case to 1-150th of a second, and even less I believe would do. After the telescope, these—with the spectroscope, which is not included in our present subject,—are the principal sources of our modern knowledge of the Sun.

Let us before exhibiting the results of this knowledge, briefly review the steps of discovery which lead to it. The ancient philosophy which held possession of men's minds from the time of Aristotle to the seventeenth century of the Christian Era, represented the Sun figuratively as "the Eye of the Universe," and literally as an orb of pure flame supported in a sphere of crystal; and few of the first discoveries of the telescope were received with more incredulity by the old school, than those of the spots on the Sun. "For some time, indeed," says Mr. Proctor, "the possibility of their existence was earnestly denied by the students of the Aristotelian philosophy. 'It is impossible,' they gravely urged, 'that the Eye of the Universe should suffer from ophthalmia."

But the existence of spots on the Sun was confirmed, and we who hear of them as of a familiar thing, can hardly understand the interest the discovery caused, the contention it aroused, and the blow to the ancient philosophy it dealt. Almost simultaneously with the discovery of the spots, it was observed by their motion that the Sun was rotating, but when it was subsequently tried to ascertain the exact time of the rotation, the most perplexingly contradictory results were obtained, and no two observers could agree on the time it took the Sun to revolve. Galileo made the period of the Sun's true revolution to be a little over 26 days; Scheiner, between 26 and 27 days; Flamsteed, 25 days and a quarter; Cassini III. 25 days and 14 hours; Lalande, 25 days and 10 hours; and thus every one found a different value. Delambre who examined and reduced a great number of observations, obtained from them something like thirty different values! He concludes that the task of finding the true time of the Sun's rotation is hopeless, and this leads him to the remark that it is a problem which every astronomer should try once in his life, and *only* once; and what is strange, he does not seem to think that these surprising differences have in them anything especially curious. Yet these enormous discrepancies were particularly strange anomalies in a science so exact as astronomy, which had even in the last century succeeded in determining the time of rotation of so relatively insignificant an object as

Mars within a few seconds. These singular discrepancies have since been explained and their cause, when discovered, threw great light on the real nature of the Sun's constitution.

It should be mentioned that an early idea had been that the spots were mountain tops or islands rising out of a fiery ocean, but that Wilson of Glasgow, in the last century advanced the opinion that they must be depressions not elevations. A spot as we shall presently see is composed of two principal divisions, a faint outer shade called the Penumbra, and a darker inner one, the Umbra, and it is easy to see that if the spot be a saucer shaped depression, in which the Penumbra is represented by the sloping sides and the Umbra by the bottom, that then, as it is approaching the edge and turned side-wise to us, the further side of the Penumbra will appear broad, and the nearer be foreshadowed, as it appears in this conventional illustration on the screen. (Illustration shown.)

The observation may appear easy; it is however very uncertain in practice, owing to the rapid changes of form the spots undergo, and the apparent tremor of the Sun's edge, due to the movements of our own atmosphere. Our entire confidence that the spots are really depressions, rests on other grounds, and is largely due to a skillful discussion of Mr. Carrington's observations by M. Faye, who has conclusively shown not only that such is the case, but that an approximate estimate of the depth of the cavity is attainable. Wilson's observation, however, led the way to a celebrated hypothesis of Sir William Herschel's, who toward the close of the last century, having considered the *facts* of an apparently dark nucleus, a light Penumbra and a brilliant photosphere, suggested that the light and heat of the Sun *might* come from an outer layer of brilliant clouds, and that the interior might be a dark and solid globe completely protected by an intermediate stratum of cloud from the outer heat, and that it might be conceivably habitable by beings like ourselves.

There are, you see, two distinct things: First the facts, second the hypothesis; but people are very apt to confound them. Herschel's views got adopted into the text-books in a more or less distorted shape and have formed the almost exclusive basis of popular instruction on this subject for the last eighty years.

Most of us who remember our own school lessons, can recollect being taught that the Sun was a solid globe, really dark, but surrounded by a sort of brilliant atmosphere, which was all we saw of it except

when a rent in the outer brightness enabled us to discover a little of the dark interior which formed the spot.

This was what we were ourselves very generally taught, and such things still remain in school books. But now, let us consider what has been found of late years, with relation to that singular fact that no exact period of rotation could be determined for the Sun. When the cause of the anomaly was discovered, it cleared our views on the nature of the Sun a good deal, as the Sun, it appeared, had no single time of rotation. Different parts required different times to rotate, a part near the solar equator not merely moving faster in miles, but making more turns about the axis in a given time, than a portion near the solar pole. Now, of course, in a solid globe, this would be impossible, and it is an irresistible conclusion that a globe whose parts revolve at different rates, and consequently with a motion on one another must be mainly liquid or gaseous.

This is quite different from what we used to be taught, but while I agree that our knowledge is not absolute, it is safe to say that though liquids and even solids may conceivably exist on the Sun, we have almost conclusive reason to believe that it is principally a gaseous or vaporous body. I have so often heard it asked how the Sun can be gaseous and yet possess the enormous mass which enables its attraction to hold this distant earth in its orbit, that I think there must be, commonly, some confusion of thought on this subject, even among the cultivated and intelligent. If to any such what I have just said cause a difficulty, the simple suggestion that a pound is equally a pound whether of gas or lead may help to remove it, and any one who wishes to realize what an enormous weight we obtain from the lightest gas, in taking enough of it, may observe that while a cubic foot of hydrogen (the lightest gas known,) weighs but about the tenth of an ounce, a cubic mile of it weighs 347,000 tons.

But we have been talking a long time about the Sun, without seeing it, and I now introduce you not to any engraving or drawing of it, but to its own autographic portrait, self-impressed, so to speak, in the transparent picture, from the fine photographs of Mr. Rutherford, which I throw on the screen.

[Three successive photographs of the Sun and spots were now exhibited, each forming a circle of about ten feet in diameter.]

Let me call your attention to the remarkable perfection of the photographs, not only the spots, but the Faculæ and minor details being shown. We see before us a faithful image of the great globe of light,

whose dimensions I could easily state in miles, but which, when we hear them, we cannot be said to comprehend. Who comprehends, for instance, the vastness of the world in which we live? Yet, here is a circle of just the proportionate size of our own globe, which I hold on the screen beside the Sun.

[The small circle in square Fig. 2 shows comparative size of the earth.]

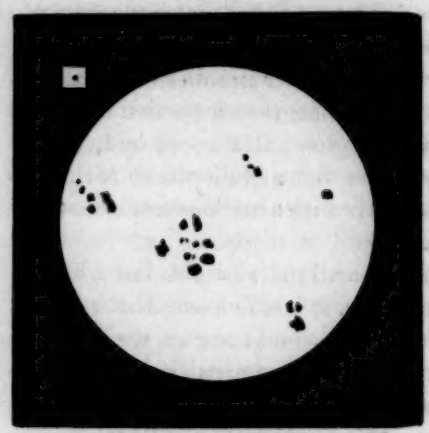


Fig. 2. The Sun, September 20th, 1870.

And if we cannot "realize" a diameter of 8,000 miles, how can we adequately conceive one of more than a hundred times that? Perhaps it will help us to the conception of this enormousness to recollect that the moon which seems so far from us, and a neighbor to the stars, is 240,000 miles distant, while the Sun's diameter is 860,000 miles. If then, the Sun were made hollow, the earth might be placed at its centre, and the moon go on revolving at her present distance, her entire orbit lying within this imaginary hollow sphere, and with several hundred thousand miles to spare. We see the large spot here as it appeared on the 20th of September, 1870, near the eastern side of the Sun.

What we know most certainly about the spots, is their enormous dimensions (obtained by methods I will try to show presently,) that they are depressions, and that they are not permanent in form or position. That is, they not only turn *with* the Sun, but have a drifting motion *on* it, and grow and change shape and disappear as they move; some living only for days, some for months. They are found almost solely in two zones, one to the north of the Solar Equator, and one to the south of it, and, though we cannot yet predict of any particular one, when it will appear, or how long it will live, we know that the spots, as a whole, have their times of maximum and minimum, or, in other words, that the Sun has periodical epochs for being covered with spots, and others for being nearly vacant of them; the period of the minimum coming considerably more than one-half the way from one maximum to another. A further very curious fact which was elucidated by Mr. Carrington, is that the frequency of the spots is in some

way related to their position on the surface, as when they are rare, those which appear lie nearer the equator than the majority do in years when they are plenty; while Messrs. De la Rue, Stewart and Loewy have shown that in times of violent solar disturbance the excess of Sun-spot area changes from the Northern to the Southern Hemisphere, and vice versa in about the time of one revolution.

This photograph was taken very near the maximum period, which occurs every ten or eleven years. These brighter portions near the edge are called faculæ, and all over the surface are mottlings.

Look well at the immense size of this spot, (it was visible to the naked eye,) and if I say that its surface is largely composed of metals turned into vapor by the intense heat, you will be prepared to hear me add that the earth on which we live, our great globe itself might be dropped into the chasm of this Umbra without touching the sides, but that this whole world of ours would be dissipated in vapor if it fell into the Sun, as a snow-flake in falling into a furnace. This seems exaggeration, perhaps. It is sober truth, no metaphor is likely to exaggerate the tremendous size—the awful power of the Sun. I hold, for instance, the drawing representing the earth, up against the Umbra of the spot, and you see that there is literally room for the earth to drop into the gulf without touching either edge. You will observe the positions of the spots here, and then in these other two photographs of September 22 and 26, which will afford an idea both of the motions of the spots in themselves, and of the changes in their appearance from the solar rotation.

Now, we naturally wish to know what exists in this immense spot; for doubtless if we could get near enough to the Sun we should see that there were all kinds of curious details to be discovered in that unknown region. But owing to various causes solar photographs cannot be magnified so as to show much detail. Mr. Rutherford's, which we have just seen, are confessedly the best ever obtained, either in this country or in Europe—even these, however, gain nothing by further magnifying, but become dim and unsatisfactory when so treated.

Here is one where a small part of the Sun containing a spot has been taken and greatly enlarged, so as to cover the whole screen, but there is nothing new told us about the spot. It is large but also vague and blurred, and tells us nothing we did not see in the small scale. I may use it however to illustrate the way in which the spots are measured. You see the wires of the micrometer projected on the

screen beside the spot. As I turn the screw, the wires move while the side remains still, and now the image of one wire just touches the eastern side of the image of the spot, and that of the other, the western. It is not a large one, and on reading the micrometer head I find that the wires are actually one-twentieth of an inch apart, while the size of the whole Sun, in the photograph which is being magnified, is (let us say) two inches. It is easy to see then, that the length of the spot is one-fortieth of the Sun's diameter, which is 860,000 miles, and a simple division shows the spot to be 21,500 miles long. The width of the spot can be measured in the same way, its irregular boundary traced, and its area calculated as a surveyor does that of a field. I have used approximate numbers, and have omitted some operations needed in practice, which however do not affect the principle of the method of such measurements, which is, as you see, quite simple.

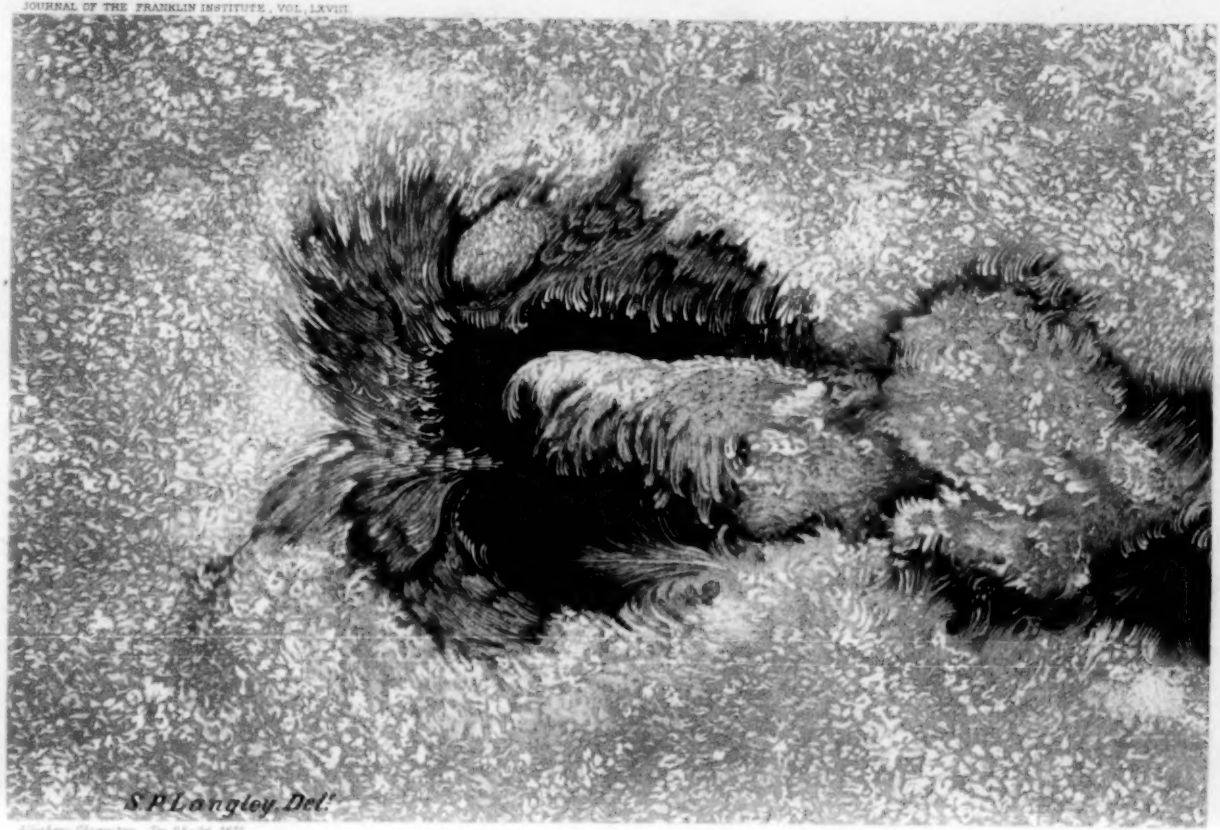
I called your attention however to the fact, that we cannot suppose this vast space to have nothing in it. Such vast dimensions in a world so like ours, must, we anticipate, be filled with curious things, if we could but get to see them, and several observers, myself among the number, have given particular attention to find out what is really there.

The difficulties are very great, but they have been partly overcome, and I wish to next show you the partial results of the labors conducted in this direction at the Allegheny Observatory in the drawings which I will now throw upon the screen.

We now have a greatly more magnified view than before, and yet you see it is not blurred by magnifying, but full of detail. We have been brought quite near to the Sun, as it were, and we can now see here for ourselves, much what till lately has been thought out of the reach of observers.

The surface of the Sun away from the spot is filled with minute white forms apparently floating in an ocean of comparatively gray fluid. The most accurate representation of them which I know in print, is in an illustration from a sketch by Huggins, given in Mr. Proctor's well known excellent work on the Sun; where will also be found a full statement of all our knowledge about them up to a very recent period.

These things, which were first noticed about ten years since, though covering in their united area but a small portion of the Sun's surface, are the principal sources of his light. These were considered most mysterious things when first discovered, and an eminent astron-


S.P.Langley Del.

omer even went so far as to suggest that they might be individual organisms. I have lately, however, been able to resolve them into smaller bodies, and while their exact nature is still undetermined, I think we may venture to speak of them as a very peculiar kind of clouds, composed, not of the vapor of water like ours, but chiefly of the vapors of iron and other metals volatilized by the intense heat; clouds which may precipitate their suspended contents as ours do rain or hail, but in a rain of molten metal, and differing from our clouds besides this in a tendency to filamentary structure, in a peculiar tenacity of form, and (conceivably) in their union of some of the properties of liquid and gaseous matter in the same substance.

You see the penumbra which appeared in the enlarged photograph, like diffuse mist, is in reality diversified by innumerable filaments, which seem like the long floating grasses bent by the whirls and eddies of a stream; but we must remember that the scale of action is here enormous, that the objects compared to blades of grass, are each thousands of miles long, and the whirls are immense cyclones moving with inconceivable velocity. We may properly call it inconceivable, for though we can measure and number, we cannot realize it. A terrestial cyclone which destroys ships and houses, is compared with this a sluggish breeze, for our tropical cyclone moves 50 to 100 miles an hour, while these demonstrably move 50 to 100 miles a *second*, as Young and others have shown.

The heat too is beyond comparison greater than that of the Simoon or any wind that sweeps over the great African desert, for the gale is here, as we shall presently see, far hotter than the air which has been forced through the glowing bed of a blast furnace.

Here is another spot, and its appearance like that of the first, is oddly suggestive of cold rather than of heat. The same sort of impression is sometimes received in looking through the open doors of a puddling furnace, at the snow-white metal. It is due here, I suppose, to the whiteness and crystal-like forms, but is of course wholly an illusion. [Reproduced in Plate I.]

Notice the curves in which the filaments sweep down to the edge of the Umbra; the really complex structure of the Umbra itself; the masses of photospheric matter islanded in the penumbra of the spot; the variety of the forms it includes; and the extremely fine subdivision of portions of the filamentary structure.

In one part is an extraordinarily symmetrical figure in which numberless fibres are disposed in nearly parallel curves, in which they

lie on each side of a central axis, with almost the regularity of a sculptured ornament. This regularity, in the present instance, is a careful transcript from nature, but yet it is quite unusual, and it is very difficult to account for the balanced symmetry of the disposition of the fibres, in the plume-like form to which I have just called attention, as compared with their irregularity in other and adjacent portions.

Before taking leave of the spot, to give an idea of its size, I will place on the screen beside it an outline of the State of Pennsylvania, drawn on the same scale as the projection.

To be continued.

RESEARCHES ON THE TEXTURE OF IRON.

By M. Janover, C. E., Metallurgist.

(Translated from the *Annales des Mines*, Vol. 5. p. 90, 1874.)

During the last fifty years, siderurgy, or the metallurgy of iron, has been enriched by a host of discoveries. New methods have been adopted in practice, old ones have been materially modified, and a large number of treatises have been written, intended to contain all the knowledge thus obtained. The art of iron-making has been raised to the dignity of a true science, though, like all the other sciences of observation, it is yet far from complete.

It is a natural assumption, that the intimate nature of a metal as important as iron, would be very perfectly known; but those metallurgists who have devoted themselves to its serious study, have not been long in perceiving that a vast field for observation still remains unexplored; and that too, in a great many directions where the subject seemed to be entirely exhausted.

The texture of iron, which is the object of this memoir, is one of those delicate questions, on which we are very willing to believe that all has been said that can be, because its study is, at least in appearsince, one of the greatest simplicity. An experience of many years however, confirmed by numerous experiments, and strengthened by various interesting communications from others, has led me to recognize the fact that the ideas upon this subject which are at present in vogue, do not at all meet the requirements of science, and that, consequently, what is commonly accepted concerning the grain of iron, must be, in great part, materially modified.

From the time of Bergmann, of Hassenfratz, and of Karsten, down to the present day, a very complete polymorphism has been given to iron, because of the want of a more exact knowledge of the causes of the various aspects under which it is presented to us in the arts.

Thus, as a result of incomplete observation, irons have been classified as granular, fibrous, and mixed granular and fibrous. And moreover, inasmuch as, from certain ores, it was easier to produce a fibrous than a granular iron, or the reverse, many metallurgists have regarded this tendency as inherent in the ore itself. Consequently such an ore is reputed to yield always fibrous iron, and such another, always granular iron.

I shall, in these pages, attempt to demonstrate that this so-called tendency to such and such a texture is not inherent in anything, and that iron is not a polymorphous body, as has been asserted by Hassenfratz and by Bergmann.

As I have already maintained,* iron presents but a single texture, and that the granular one; all others are only metamorphoses of this, due to defective temperature at the moment of finishing, which does not permit complete welding of the entire mass. Since, therefore, the grain of the iron depends only upon its more or less perfect welding, it seems to me more rational to base the classification of irons upon their weldability, of which granulations and fibres are only the effects.

Without desiring to substitute, at once, my classification into welded, non-welded, and imperfectly welded, irons, for the classification into granular and fibrous irons, which has become firmly fixed by time and use, I believe it necessary nevertheless, to regard the term granular iron as the designation of an iron perfectly welded throughout, and fibrous iron as that of a non-welded iron. The fact here embodied, now well understood and thoroughly established, is sufficient of itself to throw a flood of light upon many of the properties of iron, until now incompletely studied. Here too, we find the explanation of many of the assertions of Karsten and of other distinguished metallurgists, such as: "Soft iron becomes fibrous sooner than hard iron;" "Iron in large bars never exhibits fibres," etc. This view of the case, moreover, must be the means of correcting many popular errors: errors, too, which perpetuate themselves constantly without check, such as: "A facetted fracture, more or less course, is always

* *Annales des Mines*, xv., 1859.

the sign of a bad iron;" "A badly refined iron is recognizable at once by the facets intermingled with its fibres," etc.

The proofs which are to be urged in support of this new method of viewing irons, are very numerous. They are to be found:

1. In the different methods of manufacture.
2. In the study of iron under the microscope.
3. In the physical properties of this metal.
4. In the well established influence which certain metalloids have upon its quality.

I. PROOFS DRAWN FROM THE DIFFERENT MODES OF MANUFACTURE.

Charcoal-refined iron, that is, iron manufactured exclusively with fuel of immediate vegetable origin, and which is the purest iron known to commerce, always presents a granular texture. I will say with Karsten,* "When iron is very pure, its texture is granular," but I would add homogeneity to this and say that when iron is very pure and very homogeneous, its texture is granular.

Sometimes persons are found who think that the grain of iron is due to the hammering, that powerful means of compressing the molecules together; and that from this compression, the granular condition necessarily results. This deduction, however, is drawn only from the granular aspect presented by hammered iron compared with that of rolled iron, which latter is always more or less fibrous.

Without denying this action of the hammer, which, especially in the cold, produces in iron brilliant plane facets—which are not however, due to the inherent grain of the metal, as I shall show further on—I maintain that the grain of the iron is due, essentially, to the high temperature which exists during the last two operations; a temperature which permits the complete expulsion of the cinder and the perfect welding of the entire mass.

During the "breaking up," the refiner causes to pass before the tuyere, in the oxydizing region, all the iron, which, under the influence there present, falls piece by piece, as it were entirely melted, upon the mass beneath, the very fluid slag produced under these circumstances, favoring the operation of scaling and the perfection of the welding. This last operation, moreover, is assisted by the pressure exerted upon the mass by the workman, by means of his long rod which he uses as a lever to condense it, making a fulcrum of the furnace wall. In

**Manual of Metallurgy*, i, 58.

order to prove that the welding has been perfect, the refinery ball, after shingling, may be cut across. It will be seen at once how perfectly homogeneous and compact it is; a character entirely distinct, in these respects, from that of the ball from the puddling furnace.

The temperature at which, upon these hearths, the mass of iron has been produced, is sometimes so high that the workmen are obliged to allow it to cool a little before shingling, in order that it may not be broken in fragments under the hammer. This slight cooling, which would be a serious fault in working a puddled mass, because of the enormous quantity of cinder to be expelled, is not at all injurious to the ball from the charcoal low refining hearth. The mass has already, in the operation of refining, been completely welded together.

Puddled iron, unlike charcoal refined iron, presents quite frequently a fibrous texture. On comparing together the two processes of manufacture, it is easy to see that the temperature in the puddling furnace, is very much lower. Again, the operation of puddling consists in stirring a mass of spongy iron in the midst of a bath of cinder, which prevents the intimate approximation of its particles. Both these causes oppose the thorough welding of the mass, and consequently favor the production of a fibrous texture; since during the subsequent working, the molecules can slide over each other, thus giving to the iron its fibrous appearance.

But, it may be said, good granular iron is produced by the puddling furnace; one may easily convince himself of that fact, by a glance at the beautiful products which are turned out every day from the iron works of the Loire, such as tyres, axles, etc. And it is to the puddling too, that we owe the excellent qualities of that iron, now so much in demand. We reply, yes, it is puddling; but it is a very different process from that in use in the large English mills, and by which is made the ordinary bar iron of commerce. The difference, too, is an essential one; it is based upon the precise high temperature employed in working the granular iron, and upon a prompt hammering by which consequently, a more complete expulsion of the slag is effected, and a more perfect welding of the mass secured.

In the description which I have given* of the manufacture of granular iron, I have insisted upon the high temperature necessary for the production of this iron. I have called the attention of manufacturers to the means to be employed in order to obtain it,

**Annales des Mines*, xv, 147.

especially during the second period, that immediately preceding the formation of the balls.

Under this high temperature, which is an absolute *sine qua non*, the intimate approximation of the molecules of the iron is facilitated by the separation of the slag. I also recommend strongly, what every one who has had to make granular iron knows well, the prompt transference of the ball from the furnace to the hammer, in order that it may not have time to cool so far as to interfere with the expulsion of the slag and the welding of the metal. In order to render more palpable what I have just said upon the causes which make the distinction between granular and fibrous iron, in its manufacture, let the experiment be tried of lowering the dampers of the furnace at the moment when the puddler is ready to make up his charge into balls of granular iron, thus lowering the temperature; and then let these balls be rolled in the slag which is resting upon the hearth and carried at once, in this condition, to the hammer. These balls will now yield, when drawn out, iron entirely fibrous.

Here the puddling process itself has not been modified, and yet the iron which was granular has become fibrous. Lowering of the temperature, which has favored an incomplete welding and the distribution of slag throughout the mass, has been the only agent at work to produce this alteration of texture. This experiment appears to me conclusive.

Those siderurgists who see in the grain of iron only the influence of carbon, will probably say to me that the prolonged sojourn of this iron in the furnace, in contact with the cinder, has caused a loss of carbon; and hence, the iron being more decarbonized, it is not surprising that its texture should have changed. They are led thus to object to my theory because steel almost always has a granular appearance; and, as between iron and steel, there is only the difference of a greater or less content of carbon, they attribute its granular condition to the presence of this metalloid.

Their objection falls, however, when we reply that steel drawn out into thin plates is, not unfrequently, fibrous. Puddled steel gives this fibrous product often; but it is capable of being tempered quite as well as that which is granular. The objection, moreover, becomes entirely untenable when we state that it is possible to bring back this same fibrous iron to the granular condition by a single operation, and that not capable of giving carbon to it; i. e., by exposing it to a welding heat, which expels the cinder and permits a perfect welding.

From these facts, I believe that I am entitled to affirm that the fibrous texture of iron is not inherent in the material itself.

The transformation of the granular into the fibrous texture, either by cooling or by a deficiency of temperature at the moment of welding, may now be considered as established in an incontestable manner.

To be continued.

PHOSPHOR-BRONZE.*

By C. J. A. Dick.

Phosphor-Bronze has for some years past attracted general attention in all the scientific, military and industrial circles of Europe and the United States. The invention is due to the owners of the Belgian Nickel Works of Val-Benoit, to whom the execution of very extensive tests with different compositions of bronze for Ordnance, was entrusted by the Russian Government. They succeeded in establishing as a scientific fact, the great superiority of phosphorized alloys of copper and tin, and in advancing the manufacture of these alloys on a large scale, to a state of perfection.

Many of the European military powers have conferred upon the inventors the highest honors and decorations attainable by civilians; the several phosphor-bronze works established on the continent of Europe have been eminently successful, and in England a powerful company has recently been organized for the purpose of fully working the new alloy in all its branches and applications.

In the United States the invention was patented a few years ago, and the writer, who controls the enterprise in this country, has since obtained patents for sundry improvements. Smelting works have for some time past been in operation in Pittsburgh, Pa., producing large quantities of phosphor-bronze and supplying the Pittsburgh mills and some of our leading railroad companies. The increasing demand for this new alloy is soon to be met by the establishment of additional works in Philadelphia or New York.

The chemical action of phosphorus on the metals composing the alloy is claimed to be two-fold; on the one hand it reduces any oxides

[* The following notes on the new alloy, phosphor-bronze, were prepared by Mr. Dick for a gentleman of this city, who, deeming them of importance, has sent the paper to us for publication.—Ed.]

dissolved therein, and on the other it forms with the purified metals a most homogeneous and regular alloy, the hardness and the toughness of which are completely under control.

We give the records of some of the tests made by the highest European authorities, such as Mr. David Kirkaldy, Col. Uchatius, and the Testing House of the Prussian Royal Academy, all of which will be found of great interest.

No other metal or alloy combines in so high a degree as phosphor-bronze, the conditions of toughness, rigidity, hardness, and great elastic resistance. From the drop-tests hereafter stated, its comparative relation in this respect, to some of the best grades of wrought iron is made very apparent, and it seems almost incredible that a simple casting should not only equal, but by far overreach products upon which the most laborious working, hammering, rolling, and high mechanical skill have been expended.

Mr. David Kirkaldy's experiments with qualities of phosphor-bronze, sufficiently ductile to be drawn into fine wire, or rolled into sheets, determine its superior value as compared with brass, copper, coke-iron, charcoal-iron and steel, for all such manufactures.

The non-liability of phosphor-bronze to crystallize under heavy and often repeated strain or continued vibration, is demonstrated by the elaborate tests made and now making by the Prussian Government, the results of which, in this particular, place phosphor-bronze far above any competing material. Moreover if, jointly with this quality, the fact of the total absence of easily corroded metals, such as zinc, be taken into consideration, the advantages offered by the use of phosphor-bronze can scarcely be over-estimated. The effect of sea-water or of diluted sulphuric acid on phosphor-bronze is but slight, and much less than on copper.

A peculiarity of phosphor-bronze, the value of which will be appreciated by practical metallurgists, is, that in remelting the metal, not a particle of its component quantity of tin is "burnt out," that it makes castings of unrivaled soundness, and, that being as liquid as quicksilver, it fills even the most minute impression in the mould and can be cast in chills to great advantage. Its point of fusion is practically the same as that of ordinary gun metal.

Some of the experiments above alluded to, are stated in the following tables:

TABLE I.

Results of experiments to ascertain the Tensile Strength and resistance to Torsion of various Wires.

By MR. DAVID KIRKALDY, London.

Specimens of Wire tested.	Pulling Stress per square inch.		Ultimate extension in per ct.	Number of twists in 5 inches.	
	hard.	annealed.	annealed.	hard	annealed.
Copper	63,122 lbs.	37,002 lbs.	34·1	86·7	96
Brass	81,156 "	51,550 "	36·5	14·7	57
Charcoal Iron	65,834 "	46,160 "	28	48	87
Coke Iron	64,321 "	61,294 "	17	26	44
Steel	120,976 "	74,637 "	10·9	*	79
Phosphor-Bronze No. 1.	159,515 "	58,853 "	46·6	13·3	66
do. do. No. 2.	151,119 "	64,569 "	42·8	15·8	60
do. do. No. 3.	139,141 "	54,111 "	44·9	17·3	53
do. do. No. 4.	120,950 "	53,381 "	42·4	13	124

*Of the 8 pieces of Steel tested, 3 stood from 40 to 45 twists and
5 " " 1½ " 4 "

TABLE II.

Result of experiments to ascertain the Resistance to Extension, Set and Rupture under gradually increased pulling stress.

By the same.

Specimens.	Elastic stress per square inch.	Ultimate stress per square inch.	Ultimate permanent extension in per cent.
	lbs.	lbs.	per cent.
Phosphor-Bronze No. 1.	55,200	73,987	3·2
do. do. No. 2.	40,500	63,653	9·4
do. do. No. 3.	26,300	54,060	31.3

TABLE III.

By COL. UCHTAIUS, Director of the Imperial Ordinance Works, Vienna, Austria.

Specimens.	Absolute resistance in kilos per square centimeter.	Elastic resistance in kilos per square centimeter.	Stretch in per cent.
	kilos	kilos	per ct.
Phosphor-Bronze No. 0.	3600	600	20·66
do do No. 00.	5660	3·800	1·6
Krupp Cast Steel . .	5000	1·000	11·
Ordinary Gun Metal .	2200	385	15·

Table IV.

A.—*Tests by repeated application of direct strain.*

By the Testing-House of the Royal Academy of Industry, at Berlin Prussia; these tests are being made by order of the Prussian Government.

PHOSPHOR BRONZE.			ORDINARY GUN METAL.		
No.	Tensile strain per square in.	Number of efforts until rupture.	No.	Tensile strain per square in.	Number of efforts until rupture.
1	10 Tons.	408,350	1	10 Tons.	Broke before total strain was applied.
2	12½ "	147,850	2	10 "	4,200
3	7½ "	3·100,000	3	7½ "	6,300

B—*Tests by repeated bending in the same direction.*

PHOSPHOR-BRONZE.				ORDINARY GUN METAL.		
No.	Tensile strain per square in.	Number of Bends until rupture.		No.	Tensile strain per square in.	Number of Bends until rupture.
1	10 Tons,	862,980		1	10 Tons,	102,650
2	9 "	4 Million	not yet broken.	2	9 "	150,000
3	7½ "	3 "		3	7½ "	837,760
4	6 "	2 "				

C. *Tests by repeated double twisting.*

A bar of hammered *Phosphor-Bronze*, under a strain of 12 Tons per square inch, has until now, *without breaking*, stood more than 2½ *million* twists, whilst according to Wohler's experiments, a bar of *Krupp Cast Steel* under 12 Tons strain, *broke* after 879,700 twists, and another bar of the same under 13 Tons strain, *broke* after 1,007,-550 *twists*.

Drop-Tests made at the Pittsburgh Works.

Weight of drop 148 pounds; height of stroke 12 inches, except where otherwise stated; distance between supports, 4 inches; striking-face of drop, a blunted wedge-shape; test bars, 6 inches long, 2 inches wide, and ½ inch thick.

The letters inserted in the following table indicate the state of the surface of the test-bar, on the side upon which the blow has been given: *a*, sound; *b*, slight cracks at edge; *c*, cracks at edge increase in size; *d*, slight cracks in the middle of the test-bar; *e*, cracks in middle increase in number; *f*, cracks in middle increase in size; *g*, remains unaltered. —, straight. ⌒, test-bar reversed.

Drop Tests.

The fractions of inches stated in the table represent the permanent set of the test bar after the blow.

Metals Tested:	*Number of Blows.*																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Phosphor-Bronze, XIV., B.	3/16 a	1/4 a	3/8 a	7/16 a	1/2 a	5/8 a	11/16 a	3/4 a	25/32 a	13/16 d	7/8 g	15/16 g	1 ÷ f	3/4 a	11/16 a	9/16 d	1/2 f	3/8 f	Broke.	
Phosphor-Bronze, 6×17.	3/16 a	3/8 a	1/2 a	5/8 a	23/32 a	13/16 a	15/16 a	1″ a	7/8 a	3/4 a	9/16 a	1/2 a	3/8 a	1/4 a	— a	3 foot blows, 1″ b	a	Broke.		…
Rolled Charcoal Scrap Iron, best quality.	1/4 a	1/2 l	11/16 g	29/32 g	1 3/32 g	7/8 a	9/16 a	7/16 a	3/16 a	— a	8 foot blows, 1 5/16 a	d	Broke		…	…	…	…	…	…
Best Charcoal Fire Box Plate Iron.	5/32 a	9/32 a	7/16 b	9/16 c	11/16 c	13/16 c	29/32 c	1″ c	13/16 a	5/8 a	7/16 d	1/4 f	Broke.		…	…	…	…	…	…
The same, cut crosswise *off plate.*	3/16 b	3/8 c	9/16 c	3/4 c	Broke.	…	.....	…	…	…	.....	.	.....	…	…	…	…	…	…	…
Charcoal Tank Plate Iron.	1/8 a	9/32 b	7/16 c	9/16 c	3/4 c	Broke.	.....	…	…	…	.....	…	.....	…	…	…	…	…	…	…
Best Forged Charcoal Iron.	3/16 d	3/8 f	9/16 fe	11/16 f	13/16 f	15/16 fb	1 1/16 fe	13/16 d	11/16 f	Broke.			…	.....	…	…	…	…	…	…

It is apparent from these drop tests that the rigidity of phosphor-bronze is greatly superior to that of iron, for it takes 13 blows to bend the bar XIV B to the depth of one inch, whilst the best quality of forged charcoal iron takes eight blows, and best charcoal scrap iron but six blows for the same bend.

The strength of the phosphor-bronze bar No. 6×17 is superior to that of best charcoal scrap iron, it having stood five more blows of 12 inches than the latter before being again completely straightened, the number of blows from a height of eight feet (3) given thereafter, being the same in both cases. The relative strength of phosphor-bronze as to that of other qualities of iron tested, needs no comment.

The application of phosphor-bronze to military purposes has undergone thorough investigation. Several European governments have experimented on the use of the alloy for making cannons; without any exception the results showed a much greater resisting power over that possessed by ordinary bronze. The following instances will be of general interest:

In Belgium the ordinary bronze gun burst at the second shot, with a charge of 1 k 250 gr. (2¾lb) of powder and a cylindrical projectile weighing 8 k. 518 gr. (18¾ lbs.) The phosphor-bronze gun supported this charge perfectly; the normal charge was 500 gr. (1 1-10 lbs) of powder and 3 k. (6⅔ lbs) of projectile.

In France, the ordinary bronze gun burst at the second shot, with a charge of 1 k. 500 gr. (3½ lbs.) of powder and 16 k. (35¼ lbs) of projectile, while the phosphor-bronze gun was fired five times with this charge, and with a charge of 1 k. 750 gr. (3⅞ lbs.) of powder and a projectile of 20 k. (44 lbs.) it burst at the second shot, owing to the wedging of the projectile in the barrel. The normal charge was 550 gr. (1⅜ lbs.) of powder and a shell of 4 k. (8 4-5 lbs.)

In Prussia it was shown by firing with the regulation charges, and diminishing, at each 50 shots, the exterior diameter of the chamber, that the phosphor-bronze cannons changed their dimensions, only when the thickness of the metal was below that of the dimension of a cannon of the same calibre made of steel.

A large order has lately been given by the Prussian Navy Department to the phosphor-bronze works in Germany, for the casting of its turn-table machinery of its monitors.

Phosphor-bronze is being used in the manufacture of rifles and revolvers with good results, and by repeated re-loading of cartridge-

shells made thereof, it has been proved to resist a much greater number of discharges than any other material.

The following are some of the applications of phosphor-bronze for industrial purposes:

Pinions and Tooth Wheels.—M. M. V. Gilliaux, at Charleroi; Blondiaux at Thy-le-Chateau; Thorneycroft at Wolverhampton; De Wendel at Hayange, among many others, have used pinions and tooth wheels made of phosphor-bronze in instances where the separate parts might run the risk of sudden and violent shocks, some of these pinions weighing nearly 1½ tons. They have proved that such pinions never break, while it is found in long practice, that the teeth last double the time of those made of ordinary bronze. The alloy has for similar reasons been much employed for horological purposes and fine spur-wheels.

Tuyeres.—An article appeared in the London "*Engineering*" some time since, speaking highly in praise of phosphor-bronze as a material for tuyeres. It proved that they last far longer than similar tuyeres of ordinary bronze, and that after a year's use they presented neither sign of fissure nor incrustation by scoria of the furnace. These tuyeres have been tried in England and France, and in Germany their use has become greatly extended.

Pump Cylinders.—The perfect soundness and great resistance of phosphor-bronze make it highly suitable for the construction of barrels of pumps and hydraulic presses. Mr. Merryweather of London, is using it in his steam-fire-engines, and Messrs. McKean & Co., have extensively employed it in the construction of their St. Gothard Tunnel Machinery.

Piston Packing.—The alloy has given excellent results for this purpose; its great elasticity and the small amount of friction of its surface, gives it much advantage over the ordinary steel packing. For bushings of Connecting-Rod Eyes of the Three Cylinder Engines of Brotherhood & Hardingham, London, phosphor-bronze is found to be the only metal capable of sustaining this heavy work under high pressure steam.

Gunpowder Mill Machinery.—Extract from official pamphlet on Gunpowder Storage, published by order of the British Home Secretary:

"There is a metal known as phosphor-bronze, which may be usefully employed in connection with powder magazines. It possesses a strength little inferior to that of iron, without any liability to give forth sparks. For the keys implements and fittings, it may be usefully employed."

Heavy Shafting and Propeller Screws.—The rigidity of phosphor-bronze as shown by the foregoing tests, in combination with its great strength, make it a very valuable material for these uses; it is much in demand likewise for ships-bolts and piston rods.

Wire Cables and Ropes.—Phosphor-bronze having the advantage of not becoming crystalline under the action of repeated shocks, it is eminently fitted for making wire-rope, for submarine cables, inland wires, etc., and is unacted on by corrosive liquids as found in mines, and by the atmosphere.

It was desirable to ascertain its resistance to the chemical action of dilute sulphuric acid. For this purpose two similar sheets of copper and of phosphor-bronze were immersed in acid water of 10° Beaume strength, and at the temperature of the surrounding atmosphere; after three months it was found that the copper had lost 4·15 per cent. and the phosphor-bronze only 2·3 per cent.

Sheathing.—The alloy is readily rolled, and stands the action of sea-water much better than copper. In a comparative experiment made at Blankenberghe, lasting over a period of six months, between the best English copper and phosphor-bronze, the following results were arrived at:

The loss in weight due to the oxidizing action of the sea-water averaged for the copper 3·058 per cent. while that of the phosphor-bronze was but 1·158 per cent.

Bearings.—This most important application of phosphor-bronze has received particular attention in the United States, and most excellent results have been obtained. Any one using machinery will readily understand why a material which wears from two to five times better than best gun-metal, which is very much less liable to heat than gun-metal, and which, when heated, does not cut the journal, has received such general approval, not only by the mills in which it has been in long service, but by some of our large Railroad Corporations who have adopted it exclusively for locomotive and car brasses.

We can but say in conclusion, that a metal possessing qualities especially fitting it for such varied applications, will not fail to make its mark in all our great industries, and its price being but little over that of gun-metal, it will not only replace that alloy, but prove a most powerful competitor to iron and steel, wherever toughness, rigidity, elastic resistance and non-liability to crystallization or corrosion, are the qualities sought for.

APPENDIX.

FRANKLIN INSTITUTE EXHIBITION, 1874.

Competitive Trials of Steam Engines and Boilers.

The examination of all Steam Boilers entered for competition, will cover all the qualities comprised in the best types, and includes a test of their evaporative efficiency, which shall be one of the elements in determining which is the best.

The chief object of these comparative trials is, to display and compare publicly, the merits of the several Engines and Boilers exhibited.

A secondary object, is to reward the makers of the best Boilers and Engines.

These trials will be made under the following rules.

STATIONARY STEAM BOILERS.

1. Good Anthracite Coal of one of the following brands, viz: Buck Mountain, Harleigh Lehigh, Honeybrook Lehigh or Locust Mountain, of uniform quality and size shall be used in the furnaces of all Boilers under trial, except in those constructed especially for other kinds of fuel. The unconsumed coal, ashes and clinkers of each trial shall be deducted.

2. The feed-water shall be accurately weighed, and its temperature taken in the tanks each time they are filled, my moving the thermometer through every part of it; and also by a thermometer placed in the feed water-pipe just before it enters the boiler.

3. The steam shall be maintained in each Boiler during trial, as nearly as possible at a uniform pressure of 80 pounds per square inch. Where practicable, the dynamic value of the steam will be determined by working it through one and the same Steam Engine.

4. Natural draft only shall be used to create and maintain combustion, and its temperature as it enters the ash-pit shall be taken by thermometer, and the temperature of escaping gases by pyrometer placed in the flue, immediately beyond the Boiler, and shall be accurately noted.

5. The evaporative efficiency of each Boiler under trial shall be measured by its economic capacity for generating dry steam under the usual conditions of combustion, and best uniform and continuous management of the fires.

6. The temperature and pressure, and all other conditions of each trial shall be observed and noted at regular intervals, and shall be the same in all the trials as nearly as possible, in order to avoid complex calculations in making comparisons. Any conversions that may be necessary in making comparisons between the results of tests of different Boilers, in consequence of any necessary deviations from the conditions above stated, shall be made by Rankine's formula and tables for such purposes, [see "STEAM ENGINES, by PROF. RANKINE." pages 254, 255, 256, and 564,] and which may also be found published on pages 403 and 404 of the Journal of the Franklin Institute for December, 1873.

7. All the instruments used shall, before and after each trial, be tested in the presence of the Judges, to determine their accuracy, and all the readings of the several instruments shall be correctly noted.

8. The feed water tanks and pipes shall be placed above ground, so that leaks, if any, may be seen. The pipes leading from the feed-pumps to boilers shall have no branch connections, and the pipe from the tank to pump shall be entirely disconnected while it is being filled, and the pipe for filling the tank shall be disconnected when the pump is in operation. *All* the appliances used shall be placed in full view so that they can be observed at all times.

9. Every Boiler shall be used several consecutive days preceding the trial, in order to thoroughly dry the "setting," and the fires shall be kept up all the night previous. On commencing the trial, [the furnaces being well heated,] the fires shall be drawn—the furnace and ash-pit thoroughly cleaned—a fresh fire kindled, and at the end of the trial the fire shall again be drawn and weighed with the ashes and clinkers.

10. The Judges shall require the different firemen to exercise, as near as may be, equal skill in the management of the fires. Particular care should be taken to observe, during the continuance of the trial, that the uniformity of performance is maintained, and proper account be taken of any variations in the quantity of water or fuel used. No trial shall be of less duration than ten hours.

11. Every person assisting in making the trials, shall be under the control of the Judges, who shall have power to suspend or discharge for cause, and in this, as in all other matters pertaining to the trials, their decision shall be final.

12. In testing Steam Boilers and Engines, the following Record shall be kept, and such other information as shall be deemed of value.

Observation		Pressure by Steam Gauge.	POUNDS.		TEMPERATURES.				Intensity of flue draft in Inches.	HORSE POW'R		Height of Water.
Number	Time.	Lbs. per sq. inch.	Coal	Feed Water.	Feed Water.	Steam	Flue.	Boiler Room.		per Indicator	per Dynamom'tr	
	A	B.	C	D	E	F	G.	H	I	J		

STATIONARY STEAM ENGINES.

1 The cylinders must be drilled and tapped at each end for half-inch gas pipe, and a cock attached thereto for connecting an indicator.

2. The power of steam engines shall be taken by indicator and by dynamometer or friction brake attached directly to the engine shaft, and to facilitate this, the engine shaft should preferably project twelve inches beyond the outer bearing.

PORTABLE STEAM ENGINES.

1. The method of testing portable Engines shall, as far as practicable, be the same as those prescribed for stationary Engines and Boilers.

2. In comparing results in this class of machines, greater importance will be attached to the effect as shown by indicator and dynamometer, in comparison with the fuel consumption, than to the quantity of water evaporated by the fuel.

The Record, and all other particulars of each test together with description of Boiler or Engine, including first cost, shall be published in the report of the Judges.

Chimneys shall be furnished by the exhibitors; subject, so far as safety from fire is concerned, to the Committee on Buildings. Each exhibitor shall furnish his own fireman, or pay for same if furnished by the Institute.

The Institute will furnish the fuel for all the boilers in operation, and shall have the use and control of so many as shall be necessary to furnish steam to apparatus and machinery in operation.

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